JAEFS

International Journal of Agriculture, Environment and Food Sciences

e-ISSN : 2618-5946 DOI: 10.31015/jaefs.2021.2.2 www.jaefs.com

Research Article Int J Agric Environ Food Sci 5 (2):140-145 (2021)

Feed-value of post-harvest quinoa plant sectıons growed by different cultural applications

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Abstract

The aim of the study, the grains of the quinoa plant grown in the Kahramanmaraş region, Turkey, which was sown at different times (March 26, April 2, 13 and 26, and May 11) in various row spacing applications (20, 40 and 60 cm) was separated, and the feed-worthiness of the remaining plant sections were analyzed. The study findings demonstrated that crude protein content was 9.70-19.30%, dry matter ratio was 86.18-88.20%, acid detergent fiber content was 42.95-55.95%, neutral detergent fiber content was 51.23-64.27%, acid detergent insoluble protein content was 0.88-1.37%, digestible dry matter content was 45.3-55.4%, dry matter intake rate was 1.87-2.34%, relative feed value was 66.88-96.49%, and quality standard value varied between III and V. Mineral content was determined as follows: Ca: 0.96-1.96%, K: 1.47-2.08%, Mg: 0.17-0.74%, P: 0.18-0.37%, Tetany: 1.51-1.99, milk fever: 3.69-9.49. It was determined that the sowing time with the highest feed values for quinoa straw was May 11, while the ideal row spacing was 40 cm. Thus, a feed with higher protein and mineral content but low indigestible nutrient content could be obtained. However, it was concluded that it would be more adequate to employ the feed in composite form with other feed plants for feed quality.

Keywords: ADF, ADP, Crude protein content, Mineral content, NDF

Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a plant commonly exploited for its grains, and the leaves are consumed as vegetables. Primarily the grains of the quinoa plant have been investigated; however, it is also grown for animal forage production (Kakabouki et al., 2014). Previous studies reported that quinoa could be a valuable forage crop in dairy production and dairy farms (Podkowka et al., 2018). Generally, Gramineae and leguminous forage crops are used in animal feed. However, the available forage crops are not sufficient due to inadequate production and grazing activities. Thus, the increase in the forage demand and the need to fill the gap between forage supply and consumption require further research to determine alternative forage resources. The employment of the residue plant sections as animal forage after the quinoa seeds are separated, similar to the wheat straw, has been discussed as an alternative feed resource.

Sowing time and row spacing are the factors that affect yield in agricultural cultivation. Thus, the present study aimed to investigate the forage values of the remaining quinoa plant parts after deseeding in various sowing times and row spacing applications. Herewith, the study aimed at the employment of the residual parts of the quinoa plant, cultivated for the grains, to determine the availability of these parts for use as animal feed based on sowing time and row spacing nutrient and mineral content and feed quality. Furthermore, forage could play an essential role in improving the farmers' financial stability and contribute to the national economy.

Cite this article as:
Zulkadir, G., Idikut, L. (2021). Feed-value of post-harvest quinoa plant sectıons growed by different cultural applications. J. Agric. Environ. Food Sci., 5(2), 140-145
Doi: https://doi.org/10.31015/jaefs.2021.2.2
Orcid: Gulay Zulkadir: 0000-0003-3488-4011 and Leyla Idikut: 0000-0002-0685-7158
Received: 21 January 2021 **Accepted:** 05 April 2021 **Published Online:** 03 May 2021
Year: 2021 **Volume:** 5 **Issue:** 2 (June) **Pages:** 140-145
Available online at : http://www.jaefs.com - http://dergipark.gov.tr/jaefs

Material and Methods

Material

The trial was conducted in Kahramanmaraş province, Turkey, in 2018. In the study, quinoa (*Chenopodium quinoa* Willd.) "Q-52", which is resilient in Mediterranean climate conditions, was used as the plant material.

The analysis of soil samples collected at different depths in the trial field revealed that the soil content included moderate organic matter levels, clayey, non-saline, low phosphorus, high potassium levels, and neutral pH (Anonymous, 2018a).

According to specific climate data for 2018, total values minimum and maximum temperatures in the trial area in Kahramanmaraş province were 124.7 °C and 213.6 °C, respectively, and mean minimum and maximum temperatures were 17.8 °C and 30.5 °C, respectively. While the total precipitation in the season was 140.0 mm, the mean precipitation was 23.3 mm. During the cultivation season, the mean total temperature was 164.6°C, and the season average was 23.5°C. The average relative moisture was 336.2% in the season, and the mean moisture was 48.0% (Anonymous, 2018b).

Method

The trial was set up in 3 replicates based on the random blocks experimental design. The trials were conducted in 5 sowing times (March 26, April 2, 13, and 26, and May 11) and 3-row spacing (20 cm, 40 cm, and 60 cm) applications (4 rows per parcel). Sowing times are planned at 15-day intervals; however, due to climate conditions, 15-day application intervals varied. The seed amount sown in the trial parcels was adjusted based on the method proposed by Risi and Galwey (1991).

Based on the soil analysis findings, 5 kg^{-1}N, 6 kg^{-1}P2O5, and 6 kg^{-1}K2O were applied as essential fertilizers before sowing. Approximately 35 days after sowing, 3 kg da^{-1} N was applied as top fertilizer. Irrigation was conducted depending on the climate conditions and the water requirements of the quinoa plant. The plant samples were collected after the plant grains matured and the plant sections became yellow-brown and deseeded in the study. The plant samples were dried at 70°C for 48 hours, ground, and filtered with a 1 mm sieve.

Quality analysis was conducted on dry grass samples with a NIRS analyzer. In the analysis, crude protein content (CP), dry matter content (DMC), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent insoluble protein content (ADP), calcium content (Ca), potassium content (K), magnesium content (Mg) and phosphorus content (P) were determined. Digestible dry matter content (DDM), dry matter intake (DMI), and relative feed value (RFV) were also calculated with the ADF and NDF obtained in the analyzes (Morrison, 2003). Nevertheless, also protein content was analyzed with the micro Kjeldahl method in pulverized samples. Tetany (K: (Ca + Mg)) and milk fever (Ca: P) incidences were calculated based on milliequivalents (meq) (Aydın and Uzun, 2008).

The study data were analyzed with one-way ANOVA in SAS® 9.0 (2004) software, while Duncan multiple comparison tests were employed to determine the differences between mean scores.

Results

The analysis of variance findings and resulting groups based on DMC, CP, ADF, NDF, ADP, DDM, DMI, RFV, Ca, K, Mg, P, tetany, and milk fever parameters are presented in Table 1 and Table 2.

Crude protein content (%)

It was determined that the differences between the CP content based on ST, RS, and STxRS interactions were statistically significant in the study ($p < 0.01$). It was observed that the CP content varied between 9.70 % (II; 20 cm) and 19.30 (V; 60 cm), and the mean CP content was 13.86 %. The analysis of these figures based on the sowing times demonstrated that CP content varied between 11.96 % (II) and 17.60 % (V) and 12.69 % (20 cm) and 14.51 % (60 cm) based on RS applications.

Dry matter content (%)

Based on the ST and STxRS interaction factors, it was determined that the differences in DMC data were statistically insignificant, while they were significant based on RS ($p < 0.05$). It was observed that DMC varied between 87.07 and 87.64 % based on the RS application, and the increase in spacing led to a decrease in DMC in plants.

Acid detergent insoluble fiber (%)

It was determined that the differences in quinoa plant ADF content were statistically significant ($p < 0.01$) based on ST and STxRS interaction but insignificant based on RS ($p < 0.05$). It was observed that ADF content varied between 42.95 % (V; 20 cm) and 55.95 % (III; 60 cm), and the mean ADF content was 47.80 %. The highest ADF content was obtained in the second sowing, while the lowest ADF content was obtained in the fifth sowing.

Neutral detergent insoluble fiber (%)

Based on the NDF content, the observed differences between ST, RS, and STxST interactions were statistically significant ($p < 0.01$). The quinoa plant NDF content obtained with different applications varied between 51.23 % and 64.27%, and the mean NDF content was 57.58 %. NDF content varied between 56.09 % (I) and 60.72 % (II) based on ST and between 56.28 % (40 cm) and 58.38 % (60 cm) based on RS application. Furthermore, it was determined that there was so statistically significant difference between 20cm and 60 cm RS applications (58.1 %).

Acidic detergent insoluble protein (%)

Based on ADP, the differences between the ST applications were significant at $p < 0.01$ level, and the differences between the RS applications were significant at $p < 0.05$ level, while they were insignificant between the STxRS interactions ($p < 0.05$). ADP content varied between 1.00 % (II.) and 1.25 % (V.) based on ST. Also, the ADP content in the 1st, 2nd, and 4th sowing times was statistically in the same group with the 2nd sowing. Based on RS, it was observed that ADP content varied between 1.00 % (20cm) and 1.13 % (60 cm), and 40 cm RS was the transition group.

Digestible dry matter (%)

The study data analysis demonstrated that DDM content differed significantly based on the ST and STxRS interactions ($p < 0.01$), while the impact of the RS was insignificant. DDM content varied between 45.31 % (III; 60 cm) and 55.44 % (V; 20 cm), and the mean DDM was 51.66 %. Based on the ST application, DDM rates varied between 49.33 % (II) and 54.41 % (V).

Dry matter intake (%)

The analyses revealed statistically significant differences between DMI ($p < 0.01$) based on ST, RS, and STxRS interaction. As seen in Table 1, the DMI varied between 1.98 % and 2.15% based on the STs, and the lowest value was obtained in the 2nd ST, and the highest DMI was obtained in the 1st ST. It was determined that DMI varied between 2.06 % (60 cm) and 2.14 % (40 cm) based on RS application, and it varied between 1.87 % (II; 20 cm) and 2.34 % (IV; 40 cm) based on STxRS interaction.

Relative feed values (%)

The review of the study data on RFVs, which is an essential parameter in animal nutrition, demonstrated that the differences based on ST and STxRS interactions were significant ($p < 0.01$), and the differences based on RS applications were significant ($p < 0.05$).

While RFV varied between 75.94 % (II) and 90.46 % (V) based on ST, it varied between 82.06 % (60 cm) and 86.86 (40 cm) based on RS applications. Based on STxRS interaction, RFV varied between 66.88 % (III; 60 cm) and 96.49 % (I; 20 cm).

Calcium (%)

In the study, the analysis of the impact of applications on Ca content revealed that the differences based on RS and STxRS interactions were significant at $p < 0.01$ significance level, while STs led to significant differences at $p < 0.05$ level. Ca content varied between 1.30 % (III) and 1.64 % (V) based on ST. On the other hand, Ca content varied between 1.33 % (60 cm) and 1.60 % (20 cm) based on RS applications. It was determined that Ca content varied between 0.96 % (III; 60 cm) and 1.96 % (I; 20 cm) based on STxRS interaction.

Potassium (%)

The differences between the K content of the samples were significant at $p < 0.01$ confidence level based on ST and

Tablo 1. The analysis of variance analysis findings and resulting groups for some parameters of feed quality values

		DMC	CP	ADF	NDF	ADP	DDM	DMI
Sowing Time		NS	**	**	**	**	**	**
26 March (I)		87.59	12.73 c	46.50 bc	55.97 d	1.01 b	52.68 ab	2.15 a
2 April (II)		87.40	11.96 d	50.80 a	60.72 a	1.00 b	49.33 c	1.98 d
13 April (III)		87.09	12.19 d	49.34 ab	58.05 b	1.04 b	50.46 bc	2.07 c
26 April (IV)		87.34	14.80 b	48.08 ab	57.10 c	1.07 b	51.44 bc	2.12 b
11 May (V)		87.50	17.60 a	44.28 c	56.09 d	1.25 a	54.41 a	2.14 a
Row space (cm)		*	**	NS	**	*	NS	**
20 cm		87.64 a	12.69 b	48.04	58.09 a	1.00 b	51.47	2.08 b
40 cm		87.45 ab	14.36 a	47.01	56.28 b	1.10 ab	52.28	2.14 a
60 cm		87.07 b	14.51 a	48.35	58.38 a	1.13 a	51.23	2.06 c
Interaction		NS	**	**	**	NS	**	**
I	20 cm	88.20	13.34	43.50	53.05	1.12	55.02	2.26
	40 cm	87.26	13.43	45.81	55.55	1.03	53.21	2.16
	60 cm	87.30	11.41	50.19	59.30	0.88	49.80	2.03
II	20 cm	87.27	9.70	54.21	64.27	0.92	46.67	1.87
	40 cm	87.69	11.65	52.06	60.61	0.99	48.34	1.98
	60 cm	87.24	14.52	46.12	57.27	1.10	52.97	2.10
III	20 cm	87.47	12.74	46.37	56.59	0.99	52.78	2.12
	40 cm	87.61	13.40	45.71	54.53	1.03	53.29	2.20
	60 cm	86.18	10.44	55.95	63.04	1.09	45.31	1.90
IV	20 cm	87.58	10.69	53.19	62.68	0.94	47.46	1.91
	40 cm	87.50	16.83	46.14	51.23	1.08	52.96	2.34
	60 cm	86.95	16.89	44.91	57.39	1.20	53.91	2.09
V	20 cm	87.67	16.98	42.95	53.89	1.03	55.44	2.23
	40 cm	87.18	16.51	45.31	59.49	1.37	53.60	2.02
	60 cm	87.66	19.30	44.58	54.89	1.36	54.17	2.18

DMC: Dry matter contents, CP: Crude protein contents, ADF: Acid detergent fibre, NDF: Neutral detergent fibre, ADP: Insoluble protein content in acid detergent, DDM: Digestible dry matter content, DMI: Dry matter intake, RFV: Relative feed value, QS: Quality Standard; Ca: Calcium, K: Potassium , Mg: Magnesium, P: Phosphorus, NS: Not statistically significant, **: Important compared to $p \leq 0.01$, *: Important compared to $p \leq 0.05$.

RS, and significant at p <0.05 confidence level based on the STxRS interaction. It was determined that the K content varied between 1.62 % (V) and1.95 % (III) based on ST, between 1.69 % (20 cm) and 1.86 % (60 cm) based on RS application, and between 1.47 % (V; 20 cm) and 2.08 % (III; 20 cm) based on STxRS interaction.

Magnesium (%)

The study determined that the differences between Mg content, which is known to have a calming effect on animals, were significant (p <0.01) based on ST and STxRS interaction factors, while the effect of RS applications was insignificant on Mg content. It was determined that Mg content varied between 0.38 % (III) and 0.66 % (V) based on ST, while it varied between 0.17 % (III; 60 cm) and 0.74 % (I; 20 cm) based on STxRS interaction.

Phosphorus (%)

The impact of ST and RS applications on the P content of quinoa was statistically significant at p <0.01, while the effect of STxRS interaction was significant at p <0.05. P content varied between 0.21 % (II) and 0.33 % (V) based on ST and between 0.22 % (20 cm) and 0.28 % (60 cm) based on RS application. It was determined that P content varied between 0.18 % (II; 40 cm and IV; 20 cm) and 0.37 % (V; 40 cm) based on STxRS interaction.

Tetany

The effects of ST and RS on tetany, which is inducted by mineral imbalance and leads to paralysis in animals, were significant (p <0.01), and the impact of the STxRS interaction was significant (p <0.05). Tetany risk varied between 1.68 (V) and 1.92 (III) based on ST, 1.66 (20 cm) and 1.91 (60 cm) based on RS application, and 1.51 (V; 20 cm) and 1.99 (I; 40 cm and III; 60 cm) based on STxRS interaction.

Tablo 2. The analysis of variance analysis findings and resulting groups for some parameters of feed quality values

		RFV	QS	Ca	K	Mg	P	Tetany	Milk fever
Sowing Time		**	-	*	**	**	**	**	**
26 March (I)		87.94 ab	III	1.57 a	1.89 a	0.55 ab	0.24 bc	1.84 ab	6.94 a
2 April (II)		75.94 d	IV	1.46 ab	1.83 ab	0.51 b	0.21 c	1.80 bc	7.31 a
13 April (III)		81.52 c	IV	1.30 b	1.95 a	0.38 c	0.25 b	1.92 a	5.26 b
26 April (IV)		84.67 bc	IV	1.50 a	1.72 bc	0.54 b	0.26 b	1.71 c	6.18 ab
11 May (V)		90.46 a	III	1.64 a	1.62 c	0.66 a	0.33 a	1.68 c	5.27 b
Row space (cm)		*	-	**	**	NS	**	**	**
20 cm		83.40 b	IV	1.60 a	1.69 b	0.55 a	0.22 b	1.66 c	7.40 a
40 cm		86.86 a	III	1.56 a	1.85 a	0.57 a	0.27 a	1.80 b	6.09 b
60 cm		82.06 b	IV	1.33 b	1.86 a	0.46 b	0.28 a	1.91 a	5.08 c
Interaction		**	-	**	*	**	*	*	**
I	20 cm	96.49	III	1.96	1.72	0.74	0.23	1.63	8.46
	40 cm	89.18	III	1.35	2.00	0.44	0.27	1.99	4.97
	60 cm	78.15	IV	1.41	1.96	0.46	0.21	1.90	7.38
II	20 cm	67.56	V	1.27	1.69	0.37	0.19	1.70	6.75
	40 cm	74.21	V	1.67	1.77	0.61	0.18	1.72	9.49
	60 cm	86.05	IV	1.42	2.02	0.55	0.25	1.97	5.70
III	20 cm	86.77	IV	1.47	2.08	0.49	0.24	1.93	6.43
	40 cm	90.92	III	1.47	2.01	0.48	0.26	1.85	5.65
	60 cm	66.88	V	0.96	1.75	0.17	0.26	1.99	3.69
IV	20 cm	70.44	V	1.48	1.51	0.48	0.18	1.52	8.45
	40 cm	96.17	III	1.72	1.77	0.65	0.29	1.68	6.05
	60 cm	87.39	III	1.29	1.88	0.48	0.32	1.95	4.05
V	20 cm	95.72	III	1.80	1.47	0.69	0.26	1.51	6.93
	40 cm	83.83	IV	1.57	1.73	0.65	0.37	1.78	4.29
	60 cm	91.84	III	1.56	1.67	0.65	0.35	1.75	4.58

DMC: Dry matter contents, CP: Crude protein contents, ADF: Acid detergent fibre, NDF: Neutral detergent fibre, ADP: Insoluble protein content in acid detergent, DDM: Digestible dry matter content, DMI: Dry matter intake, RFV: Relative feed value, QS: Quality Standard; Ca: Calcium, K: Potassium , Mg: Magnesium, P: Phosphorus, NS: Not statistically significant, **: Important compared to p≤0.01, *: Important compared to p≤0.05.

Milk fever

Based on milk fever risk values, the effects of ST, RS, and STxRS interaction were statistically significant (p <0.01). While the milk fever risk varied between 5.26 (III) and 7.31 (II) based on ST, it varied between 5.08 (60cm) and 7.40 (20cm) based on RS application. It was determined that it varied between 3.69 (III; 60cm) and 9.49 (II; 40cm) based on STxRS interaction.

Discussion

Crude protein content (%) and Dry matter content (%)

The previous studies conducted on various quinoa varieties reported crude protein content between 13.5 and 17.7 % during the flowering period (Temel and Keskin, 2019), between 16.3 and 17.8 % in physiologically mature plants (Tan and Temel, 2017), between 11.3 and 13.6 % (Kaya and Aydemir, 2020). Although the present study findings were mainly consistent with other studies conducted with quinoa, specific differences were observed due to the effect of the harvest period.

Sayar et al. (2018) reported that DMC varied between 88.9 and 91.7% in certain poaceous forage crops, Khan et al. (2017) reported that DMC varied between 89.2 and 95.1% in 6 weeds, Gürsoy and Macit (2016) determined that DMC varied between 92.6 and 95.6% in certain poaceous forage crops. The present study findings were lower when compared to the data reported in other research. This difference in result could be due to the diversity between the studied plant species.

Acid detergent insoluble fiber (%) and Neutral detergent insoluble fiber (%)

It was determined ADF ratio varied between 22.8 and 26.9% (Temel and Keskin, 2019), between 17.9 and 30.5% (Kaya and Aydemir, 2020) in quinoa varieties, between 22.9 and 43.2% in certain gramineae forage plants (Sayar et al., 2018). It could be observed that previous study findings on quinoa were lower when compared to our findings. The difference in findings could be associated with the forage crop harvest dates since fodder was used as the present study material. During the maturation period, the changes in plant cell wall components lead to an increase in ADF content (Kaplan et al., 2017). On the other hand, the differences between the previous and current study findings were due to genotypical, ecological, cultural, and analytical factors (Başbağ et al., 2018).

In previous studies, NDF was determined as 42.3-45.2% for 6 quinoa varieties (Kaya and Aydemir, 2020), as 38.0-43.5% in quinoa (Temel and Keskin, 2019). Although the present study findings were similar to previous reports, it could be observed that the NDF content varied within a wide range. This variation was caused by several factors, especially plant species, varieties, development period of the plant, and ecological conditions.

Acidic detergent insoluble protein (%) and Digestible dry matter (%)

The previous studies on ADP reported that it varied between 0.08 and 0.63% in certain poaceous species (Başbağ et al., 2018). The present study findings were higher than those reported in previous studies. It was suggested that the differences were due to plant species, the harvest periods, and employed plant parts. The present study suggested that the high ADP content was since the harvested plants had reached physiological maturity and the stem volume was higher than the leaf volume, especially after harvest.

In some works of literature, DDM content varied between 65.1 and 67.2 % in various quinoa species (Kaya and Aydemir, 2020) and 68.0 and 71.1 % (Temel and Keskin, 2019) based on row and inter-row spacing applications.

Dry matter intake (%) and Relative feed values (%)

The studies conducted on quinoa reported that DMI varied between 2.8 and 3.2 % (Temel and Keskin, 2019) and between 2.7 and 2.8 % (Kaya and Aydemir, 2020). It was suggested that the compatibility of these figures with the present study was because all were conducted with the same plant species and the differences were due to harvesting in the flowering period.

Previous studies reported that RFV varied between 134.4 and 147.6 (Kaya and Aydemir, 2020), between146.3 and 173.2 (Temel and Keskin, 2019), between 68.9 and 143.1 (Başbağ et al., 2018), between 86.8 and 197.0 (Gürsoy and Macit, 2016). These figures were inconsistent. This inconsistency could be due to the employment of different species and varieties as roughage. It was determined that cultural processes, climate, ecology, and even the harvest in the phenological period also impacted RFV even when the same species and varieties are used.

Calcium (%) and Potassium (%)

Certain studies reported that Ca content varied between 1.0 and 3.3 % in 9 quinoa varieties (Tan, 2020) and between 0.83 and 1.27 % in 6 quinoa varieties (Kaya and Aydemir, 2020). Although the previous study findings were consistent with our findings, it was observed that Ca content was lower in various plant species. Debski et al. (2013) reported that Ca content varied based on variety, and the quinoa plant was quite rich in Ca.

The previous study findings that K content varied between 2.9 and 3.3% (Kaya and Aydemir, 2020) and 1.5 and 2.3% (Tan, 2020). It was observed that the present study findings were consistent with previous studies and reported ideal K levels.

Magnesium (%) and Phosphorus (%)

Mg content reported in studies investigating the feed-worthiness of various quinoa varieties was 1.0-2.3% (Tan, 2020) and 2.7-4.3 (Kaya and Aydemir, 2020). While these figures were higher than those reported in the present study, Nurfeta et al. (2008) reported that Mg content varied significantly among different varieties of the same plant species.

Furthermore, since the Mg content is higher (Chen et al., 2018) at growth extremities and young leaves compared to other sections, it is higher in plants harvested during the flowering period compared to those harvested during physiological maturity. On the other hand, it was found that quinoa had higher Mg content than certain other forage plants. It was suggested that our findings were high due to the variety and different harvest periods.

Phosphorus content reported in previous studies varied between 0.27 and 0.42 % (Kaya and Aydemir, 2020), 0.7, and 1.8 % (Tan, 2020) in different quinoa varieties. In the present study, the P content was low since we harvested the crops after physiological maturity and analyzed the residue plant sections after deseeding. However, it was determined that the P content in barley, oat, triticale straw, and their intercrop cultivation with peas were lower when compared to the quinoa straw; thus, quinoa is an excellent alternative crop.

Tetany and Milk fever

Tan (2020) analyzed the use of quinoa plants as feed and reported that the tetany risk varied between 1.5 and 3.0 and MF value varied between 0.5 and 3.8% and also, he was reported that intensive use of certain varieties might lead to milk fever risk. It was suggested that the present study findings were higher than the ideal range, and quinoa should not be used alone and at high rates.

Conclusions

The application of the quinoa plant, global recognition, and production of which has been increasing since the last decade is not limited to the use of its grain, but the straw could be used as feed. In studies conducted on the cultivation of quinoa as a forage crop, the feedworthiness of the plant has been investigated. In sowing conducted in May with a row spacing of 40 cm, it was determined that high protein and mineral content and low hard-to-digest agents were produced. On the other hand, its use as intercrop feed with other forage crops was suggested due to non-ideal ADF, NDF, ADP, and MF content. However, the fact that the feed quality is affected by all conditions requires further studies to acquire more detailed information on quinoa cultivation. Thus, the present study concluded that the potential of quinoa as feed was high, and it would help eliminate the existing feed shortage.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

Funding

No financial support was received for this study.

Data availability

Not applicable.

Consent for publication

Not applicable.

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