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COMPARISON OF DIFFERENT LINSEED GENOTYPES MEAL IN TERMS OF FEED VALUE PROPERTIES

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Abstract: This study was conducted to determine the nutritional content and nutritive values of some varieties of linseed meal. For this purpose, neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), crude ash (CA), and crude protein (CP) analyses were performed on meals obtained from 13 different linseed varieties (Clli 1423, Larkana, Milas, NewTurk, Dillman, Sari-85, Clli 1351, Clli 1370, Clli 1400, Clli 1412, Karakız, Beyaz Gelin, Noreum) in order to determine some nutritional content. Based on some data obtained from these analyses, nutritive values such as dry matter digestibility (DMD), dry matter intake (DMI), relative feed value (RFV), metabolizable energy (ME), and net energy for lactation (NEL) were calculated. In terms of nutritional content, the NDF, ADF, ADL, and CP contents of linseed meals were found to be significant, while the CA content was not found to be significant. The NDF, ADF, ADL, and CP contents of the meal varied within the ranges of %58.40-96.37, %18.62-35.64, %8.55-20.45, and %34.84-41.21, respectively. In terms of nutritive value characteristics, the DMD, ME, and NEL properties of linseed meal were found to be significant, while the DMI and RFV features were deemed insignificant. The DMD, ME, and NEL values of the meal varied within the ranges of %61.14-74.39, 9.35-11.91 MJ/kg, and 1.37-1.81 Mcal/kg, respectively. In conclusion, it was determined that among the linseed varieties, the highest results in terms of both nutritional content and nutritive value were provided by the NewTurk variety, while the worst results were generally observed in the Beyaz Gelin variety. However, it was concluded that the meals from all evaluated linseed varieties could be utilized in the intensive feed industry.

Keywords: Linseed, Linseed meal, Nutritional content, Nutritive value, Feed

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1. Introduction

Linseed (*Linum usitatissimum* L.) is a species cultivated for its fibers and seeds within the Linaceae family. While linseed genotypes are typically grown in continental climate regions, fiber linseed genotypes thrive in cool, moist climate conditions (Zuk et al., 2015). Presently, linseed is a versatile crop cultivated for its seeds, fibers, and for dual-purpose production (both seed and fiber), with a height range of 60-120 cm depending on the variety, planting density, and weather conditions (Muir and Westcott, 2003; Mert, 2020; Aygün and Mert, 2022). Its fibers are primarily used in the textile industry, while its seeds, rich in healthy oils and high in protein content, find application in various food products as well (Aygün et al., 2024).

While linseed seeds are consumed directly, they are also used to obtain oil through cold pressing methods (Nykter et al., 2006). Linseed oil is rich in omega-3 fatty acids, making it a recognized source of healthy fats widely used by people (Tripathi et al., 2013). After extracting oil from linseed seeds, the remaining residue is referred to as linseed meal or cake.

Meal is typically the term given to the residue left after extracting oil from oilseeds (Katok-Öztürk, 2020). This material is usually rich in nutritious components such as fibers, proteins, vitamins, minerals, and antioxidants (Onat et al., 2017). However, the exact composition of meal, including the proportions of different nutrients, can vary depending on the content and type of the oilseed from which it is obtained. Meal is commonly used in animal feed production, serving as an additional source of fiber and nutrients for animals (Şahin et al., 2018). It is particularly prevalent in the diets of cattle, goats, sheep, and poultry.

Research on the evaluation of linseed meal for animal nutrition, including its nutrient content and nutritive value, is quite limited. This study aims to investigate the nutrient content and feeding value of linseed meals obtained from various linseed genotypes.

2. Materials and Methods

In this study, 13 linseed (*Linum usitatissimum* L.) genotypes (Clli 1423, Larkana, Milas, NewTurk, Dillman, Sarı-85, Clli 1351, Clli 1370, Clli 1400, Clli 1412, Karakız, Beyaz Gelin, and Noreum) were used as plant materials.. This investigation was carried out according to randomized block design with three replications. The plants were sown in December 2020 at the Research and

Application Field of Mustafa Kemal University in Hatay, and harvested in June 2021. Experimental field has a Mediterranean climate located south of Turkiye and east of the Mediterranean region (annual mean rainfall is approximately 600 mm). The detailed chemical and physical properties of the soil at the experimental site are given in Table 1. The soil texture of the experimental field had a clay structure, and the lime content was moderate. Additionally, the organic matter, phosphorus and potassium contents of the soil at the experimental site were very low. Climatic data (Anonymous, 2022) from the experimental field for the growing season (2020-2021) and long-term averages are given in Figure 1. The April, May and June temperatures during the growing season were greater than those during the long-term years. The temperatures in the late autumn and winter months were similar to the long-term temperature data. The rainfall in December, January and March of the growing season was greater than that the long-term years. In the growing season, there was a higher rainfall value than that in the long-term years for all months except for January.

Each linseed genotype was cultivated in plots measuring 5 meters in length. The plots consisted of 5 rows, with row spacing set at 20 cm. During cultivation, 100 kg ha^{-1} of nitrogen was applied, with half applied at the time of sowing and the other half during the flowering stage. Additionally, phosphorus and potassium were applied at a rate of 50 kg ha^{-1} at the time of sowing. No irrigation was provided during the growing season, and the plant's water needs were met solely through natural rainfall. After harvesting, the seeds were removed from the capsules and ground. Afterward, the oil extraction of the seeds was conducted using the Soxhlet extraction method, following the AOAC guidelines from 2005.

The nutrient content and feeding value of the meal from the linseed genotypes were determined using the scientific methods outlined below:

The NDF (Neutral Detergent Fiber), ADF (Acid Detergent Fiber), and ADL (Acid Detergent Lignin) contents (% DM) of the obtained meal were analyzed using the protocols outlined by Van Soest et al. (1991) with the Ankom Fiber Analyzer device.

The crude protein (CP) and crude ash (CA) contents (DM%) of the meal were determined according to the AOAC (Association of Official Agricultural Chemists) guidelines from 1990. The CP content of the meal was determined using the Kjeldahl method, while the CA content was determined by incinerating the samples in a muffle furnace.

Dry Matter Digestibility (DMD), Dry Matter Intake (DMI), and Relative Feed Value (RFV): These characteristics were calculated using the formulas expressed in Equations 1-3, as outlined by Van Dyke and Anderson (2002).

$$DMD\ (\%) = 88.9 - (0.779 \times ADF\%) \tag{1}$$

$$DMI\ (\%) = \frac{120}{NDF\%} \tag{2}$$

$$RFV = DMD \times DMI \times 0.775 \tag{3}$$

Metabolizable Energy (ME) and Net Energy for Lactation (NEL): These characteristics were calculated using the formulas provided in Equationd 4 and 5:

$$ME\ (MJ\ kg^{-1}\ DM) = 14.70 - (0.150 \times ADF\%) \tag{4}$$

$$NEL\ (Mcal\ kg^{-1}\ DM) = \left(1.044 - (0.0119 \times ADF\%)\right) \times 2.205 \tag{5}$$

The data obtained from this study were subjected to analysis of variance (ANOVA) to determine the differences among the linseed genotypes via statistical program of Statistica. For characteristics found to be significant (P<0.05) in the analysis of variance, Tukey's honestly significant difference (HSD) test was applied for multiple comparisons (Genç and Soysal, 2018).

Table 1. Detailed chemical and physical properties of the soil at the experimental site

Properties	Method	Unit	Results	Results
pH	Potentiometric	-	7.43	Slightly alkaline
Conductivity	Potentiometric	µS cm^{-1}	328	Negligible
Useful phosphorus (P)	Spectrophotometric	kg da^{-1}	2.4	Low
Useful potassium (K)	Spectrophotometric	kg da^{-1}	85.4	High
Calcium (Ca)	Spectrophotometric	ppm	8900.0	High
Iron (Fe)	Spectrophotometric	ppm	14.0	Low
Copper (Cu)	Spectrophotometric	ppm	1.6	Low
Manganese (Mn)	Spectrophotometric	ppm	20.7	Low
Zinc (Zn)	Spectrophotometric	ppm	2.3	Low
Magnesium (Mg)	Spectrophotometric	ppm	1679.2	High
Organic matter	Walkley-Black	%	1.7	Low
Lime	Calcimetric measurement	%	2.4	Low
Saturation	Saturation with water	%	72.6	Clay

Figure 1. Monthly total rainfall and monthly mean temperature at the experimental site during the growing season (2020–2021 and 2021–2022) and in the long term (1940–2021).

3. Results and Discussion

The NDF contents of linseed meals have been significantly affected by genotype (P<0.05) (Table 2). The NDF content varied between 58.40% and 96.37%. It has been determined that the variability range of NDF content among genotypes (a difference of 37.97%) is quite high. The highest NDF content was observed in the Karakız genotype, while the lowest was found in the Dillman genotype. An NDF content exceeding 50% in directly fed feeds (concentrate or roughage) may lead to digestive problems (Yavuz, 2005). It has been reported that the most appropriate NDF content for feeds should be between 25-32% (Tekce and Gül, 2014). On the other hand, linseed meal s are used to complement insufficient NDF content in concentrating feeds. In this regard, it can be concluded that the genotypes assessed here may not be suitable for direct feed use but could be utilized as feed raw materials.

Table 2. Results of variance analysis and multiple comparison tests for nutrient content of linseed meal from various genotypes

Genotypes	NDF (% DM)	ADF (% DM)	ADL (% DM)	ASH (% DM)	CP (% DM)
Clli 1423	67.43±7.32 ab	20.42±2.24 d	9.50±1.41 d	6.65±0.38	39.69±0.49 abc
Larkana	69.10±7.66 ab	21.80±1.75 cd	10.29±0.83 d	7.08±0.22	37.08±1.97 abc
Milas	64.27±6.71 ab	19.31±0.36 d	8.66±0.22 d	7.65±0.50	38.69±0.38 abc
NewTurk	62.33±4.70 ab	18.62±2.17 d	8.55±1.56 d	7.40±0.94	41.21±0.83 a
Dillman	58.40±5.82 b	19.55±2.56 d	10.09±1.55 d	7.39±0.61	38.71±0.85 abc
Sarı-85	81.38±7.76 ab	22.14±1.84 cd	9.72±1.81 d	7.85±0.40	40.68±0.64 ab
Clli 1351	64.82±11.36 ab	22.02±2.77 cd	10.08±2.46 d	6.68±0.08	40.40±1.65 abc
Clli 1370	67.58±7.54 ab	22.21±2.60 cd	10.69±2.12 cd	6.78±0.12	40.78±0.70 ab
Clli 1400	71.79±8.39 ab	22.58±2.57 bcd	11.23±2.45 bcd	6.63±0.23	40.63±1.16 ab
Clli 1412	68.39±4.43 ab	25.17±2.29 abcd	13.25±1.21 abcd	6.50±0.39	39.68±1.46 abc
Karakız	96.37±3.48 a	33.01±0.99 abc	18.55±1.21 abc	6.32±0.14	35.69±0.51 abc
Beyaz Gelin	86.35±7.01 ab	35.64±3.52 a	20.45±2.32 a	6.34±0.16	34.84±0.19 c
Noreum	66.51±1.34 ab	33.72±0.94 ab	18.80±0.08 ab	6.53±0.06	35.46±1.16 bc
Coef. Var.	20.08	26.82	38.20	11.05	6.84
SEM	2.29	1.04	0.75	0.12	0.42
F	2.52*	7.16**	7.19**	1.66 ns	4.23**

*= P<0.05, **= P<0.01, ns: non-significant, Coef. Var.= coefficient of variation, SEM= standard error of the mean.

Table 3. Variance analysis and multiple comparison test results of feeding values for meals from various linseed genotypes

Genotypes	DMD (%)	DMI (%)	RFV	ME (MJ/kg KM)	NEL (Mcal/kg KM)
Clli 1423	72.99±1.74 [a]	1.82±0.19	103.48±12.96	11.64±0.34 [a]	1.77±0.06 [a]
Larkana	71.92±1.37 [ab]	1.78±0.19	99.54±12.52	11.43±0.26 [ab]	1.73±0.05 [ab]
Milas	73.86±0.28 [a]	1.91±0.22	109.54±12.82	11.80±0.05 [a]	1.80±0.01 [a]
NewTurk	74.39±1.69 [a]	1.95±0.16	112.78±11.83	11.91±0.33 [a]	1.81±0.06 [a]
Dillman	73.67±1.99 [a]	2.10±0.21	119.74±12.93	11.77±0.38 [a]	1.79±0.07 [a]
Sarı-85	71.66±1.43 [ab]	1.50±0.13	83.49±8.57	11.38±0.28 [ab]	1.72±0.05 [ab]
Clli 1351	71.75±2.16 [ab]	2.00±0.42	112.56±27.51	11.4±0.42 [ab]	1.72±0.07 [ab]
Clli 1370	71.60±2.02 [ab]	1.83±0.22	101.94±15.28	11.37±0.39 [ab]	1.72±0.07 [ab]
Clli 1400	71.31±2.00 [abc]	1.72±0.22	95.86±15	11.31±0.39 [abc]	1.71±0.07 [abc]
Clli 1412	69.29±1.78 [abcd]	1.77±0.11	95.29±8.29	10.92±0.34 [abcd]	1.64±0.06 [abcd]
Karakız	63.18±0.77 [bcd]	1.25±0.04	61.18±2.88	9.75±0.15 [bcd]	1.44±0.03 [bcd]
Beyaz Gelin	61.14±2.74 [d]	1.41±0.12	67.24±8.60	9.35±0.53 [d]	1.37±0.09 [d]
Noreum	62.63±0.74 [cd]	1.81±0.04	87.60±0.76	9.64±0.14 [cd]	1.42±0.02 [cd]
Coef. Var.	7.26	20.98	26.37	8.85	10.29
SEM	0.81	0.06	4.06	0.16	0.03
F	7.16**	1.53 [ns]	1.86 [ns]	7.16**	7.16**

*= P<0.05, **= P<0.01, ns: non-significant, Coef. Var.= coefficient of variation, SEM= standard error of the mean.

The ADF contents of the linseed meals have been significantly affected by genotype (P<0.01) (Table 2). The ADF content varied between 18.62% and 35.64%. The highest ADF content was observed in the Beyaz Gelin, while the lowest was found in the NewTurk (Table 2). Inadequate ADF content in ruminant diets can lead to various disorders (Tekce and Gül, 2014). The ADF contents obtained from this study are sufficient for animal feeding purposes. Direct feeding of ruminants with feeds containing higher ADF content, such as those with 28% ADF or more, may lead to various health problems (Yavuz, 2005). Therefore, it would be more appropriate to use the linseed meals from some of the genotypes assessed in this study as raw materials for concentrate feeds.

The ADL contents of the linseed meals have been significantly affected by genotype (P<0.01) (Table 2). The ADL content varied between 8.55% and 20.45%. The highest ADL content was found in Beyaz Gelin, while the lowest was in the NewTurk (Table 2). High ADL content is one of the significant factors adversely affecting digestion in ruminants (He et al., 2018). Based on the ADL contents obtained from this study, it can be inferred that genotypes with ADL content exceeding 10% are generally unsuitable for direct feeding. However, considering the cell wall components (structural carbohydrates) of all linseed genotypes, it can be suggested that meals from the NewTurk and Milas could be used directly for ruminant feeding. Nonetheless, it would be more appropriate to use the meals from these linseed genotypes as raw materials in the concentrate feed industry due to their cell wall component profiles.

The CA contents of the linseed meals were not significantly affected by genotype (P>0.05) (Table 2). In contrast, the CP contents were significantly affected by genotype differences (Table 2). The CP content ranged from 34.84% to 41.21%. The highest CP content was observed in the NewTurk, while the lowest was found in the Beyaz Gelin (Table 2). The CP contents in soybean, canola, cotton, sunflower, and peanut meals have been reported as 48%, 35%, 39%, 30%, and 46%, respectively (Willis, 2003). According to the results from this study, the CP contents of the genotypes are higher than those in sunflower meal. Furthermore, some genotypes exhibited higher CP content compared to both canola and cotton meals.

The variation and mean comparison results for DMD, DMI, RFV, ME, and NEL of the meals derived from different linseed genotypes are presented in Table 3. As shown in Table 3, significant differences in DMD, ME, and NEL properties were observed among the genotypes. The highest DMD value (74.39%) was obtained from the NewTurk genotype, although statistically similar values were found in other genotypes. The lowest DMD value (61.14%) was determined in the Beyaz Gelin genotype. Some DMD values for certain genotypes in this study (70%-75%) were found to be similar to the DMD values of alfalfa hay (Jančík et al., 2017). Thus, many of the genotypes used in the study were deemed significant. The ME values for the linseed meals ranged from 9.35 MJ kg^{-1} DM to 11.91 MJ kg^{-1} DM, with the highest ME value obtained from the NewTurk genotype and the lowest from the Beyaz Gelin genotype. Cordeiro et al. (2022) found the ME value of sunflower meal to be 12.13 MJ kg^{-1} DM, while Brand et al. (2000) reported it as 13.76 MJ kg^{-1} DM for canola meal. Although the ME values obtained in this study are close to literature reports, they are lower, which can be attributed to differences in the types of meals. The highest NEL value (1.81 Mcal kg^{-1} DM) was found in the NewTurk genotype, while the lowest (1.37 Mcal kg^{-1} DM) was in the Beyaz Gelin genotype. The NEL values of the genotypes were found to be similar to those of many roughage crops (Atasever et al., 2020; Yılmaz et al., 2018).

4. Conclusion

This study aimed to determine the nutritional content and feeding values of meals derived from different linseed genotypes. Among these genotypes, the NewTurk genotype yielded the most superior results in terms of both nutritional content and feeding values, while the Beyaz Gelin genotype showed the least favorable results. Overall, it was concluded that the meals obtained from all genotypes could potentially serve as good concentrate feed additives in terms of both nutritional content and feeding values.

Author Contributions

The percentage of the author(s) contributions is presented below. The author reviewed and approved the final version of the manuscript.

	İ.E.	Y.Z.A.	M.M.
C	50	50	
D	50	50	
S			100
DCP	50	50	
DAI	100		
L	100		
W	50	50	
CR	25	25	50
SR	50	50	

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

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