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The Crude Nutrient Values Comparison of Corn Silages from some Provinces of Türkiye using Near Infrared Spectroscopy (NIRS) [*]

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Abstract: In this study, a total of 216 corn silage samples collected from 6 provinces (namely Aksaray, Balıkesir, İzmir, Kırşehir, Konya and Niğde) over a period of one year were analyzed using Near Infrared Spectroscopy (NIRS) method. The lowest moisture content was found in silage samples from Balıkesir and Kırşehir, whilst the highest was in those from Konya (P<0.01). The differences between the silages collected from İzmir, Kırşehir, Konya and Niğde were not significant in terms of crude cellulose (CC), but they were all significantly lower than Aksaray (P<0.01). The highest acid detergent fibre (ADF) content was observed in Balıkesir and Kırşehir (P<0.01). Neutral detergent fibre (NDF) content was the lowest in Konya, İzmir and Kırşehir and the highest in Aksaray (P<0.01). Crude protein (CP) content was lowest in silage samples from Niğde and highest in samples from Aksaray (P<0.01). As to ether extract (EE) Aksaray, Konya and Niğde had the lowest content whereas Balıkesir had the highest average value (P<0.01). The provinces with the lowest starch content were Aksaray, Konya and Niğde, while Balıkesir and Kırşehir were the ones with highest values (P<0.01). Aksaray had the highest crude ash (CA) average (P<0.01). In conclusion, the chemical nutrient compositions of the analyzed corn silage samples were significantly influenced by their provinces of origin (P<0.01). Additionally, it was concluded that NIRS technology could be useful for rapid and accurate determination of silage quality.

Keywords: Corn silage, forage, crude nutrients of feeds, NIRS.

Türkiye'nin Bazı İllerindeki Mısır Silajlarının Yakın Kızılötesi Spektroskopisi (NIRS) Kullanılarak Ham Besin Değerlerinin Karşılaştırılma

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Öz: Bu çalışmada, toplam bir yıl süreyle, Aksaray, Balıkesir, İzmir, Kırşehir, Konya ve Niğde olmak üzere 6 ilden temin edilen toplam 216 adet mısır silajı örnekleri Yakın Kızılötesi Spektroskopisi (NIRS) kullanılarak analiz edildi. Nem içeriği en düşük Balıkesir ve Kırşehir'den, en yüksek Konya'dan elde edilen silaj örneklerinde saptandı (P<0.01). İzmir, Kırşehir, Konya, Niğde'den elde edilen silajların ham selüloz bakımından aralarındaki farklar önemsiz iken, Aksaray'a göre daha düşük bulundu (P<0.01). En yüksek acid detergent fiber (ADF) içeriği Balıkesir ve Kırşehir'de gözlendi (P<0.01). Neutral detergent fiber (NDF) içeriği en düşük iller Konya, İzmir ve Kırşehir, en yüksek il ise Aksaray'dı (P<0.01). Ham protein içeriği en düşük Niğde'den, en yüksek Aksaray'dan alınan silaj örneklerinde tespit edildi (P<0.01). Ether extract (EE) içeriği en düşük iller Aksaray, Konya ve Niğde iken en yüksek ortalamaya sahip il Balıkesir'di (P<0.01). Nişasta ortalaması en düşük iller Aksaray, Konya ve Niğde, en yüksek iller ise Balıkesir ve Kırşehir olarak bulundu (P<0.01). Ham kül ortalaması en yüksek il Aksaray'dı (P<0.01). Sonuç olarak, mısır silajının yetiştirildiği iller, analiz edilen örneklerin kimyasal besin bileşenlerini büyük ölçüde etkiledi (P<0.01). Ek olarak, NIRS teknolojisinin silaj kalitesinin hızlı ve doğru belirlenmesi açısından faydalı olabileceği sonucuna varıldı.

Anahtar kelimeler: Mısır silajı, kaba yem, yemlerin ham besin maddeleri, NIRS.

INTRODUCTION

The supply of forages, which are essential components of ruminant nutrition, may become problematic in some certain periods. Silage is an important forage source due to a number of reasons such as the difficulty of sourcing green forage in winter, insufficient quality of available pastures, and closed system barns in farms. Thanks to silages, moisture rich forage can be provided to ruminants throughout the year, grasses can be fed to animals preserving

their freshness, and nutrient loss can be minimized. Quality and efficiency of silage production is dependent on various factors such as agricultural infrastructure, vegetation period, harvesting and ensiling practices, and feed-out methods. However, the primary determining elements are the nutritional value and chemical composition of the ensiled material, and the climate of the growing region (Bernardes et al., 2018).

In recent years, corn has become a crop of rapidly increasing importance with the expansion of its usage areas, both in the world and in Turkey. Corn, one of the most common and widely cultivated cereals, is a feed crop providing high biomass yield, high digestibility, energy and dry matter content. It is the most easily ensilable forage crop thanks to its high level of readily degradable carbohydrate content and favorable buffer capacity. In addition to these attributes, it is an indispensable forage source as it is a highly palatable feedstuff for ruminants and is rich in energy. In order to obtain a good quality and productive silage, it is important to determine the harvest time taking into consideration the dry matter content, dry matter yield per cultivated area, and digestibility of dry matter (Mandić et al., 2018). The most suitable ensiling time is the dough maturity period, following the completion of the kernel milk stage. When harvested during this period, it has homogeneous harvest quality, adequate dry matter ratio, and favorable carbohydrate content for fermentation, and low buffer capacity. All these characteristics can vary significantly depending on the region where the plant is grown and environmental conditions (García-Chávez et al., 2022; Kurtoğlu, 2011). These differences directly affect the quantitative and qualitative efficiency of the product, resulting in changes in the productivity and quality of silage (Neumann et al., 2024).

Corn is a plant that can be ensiled in a wider vegetation range than other crops. It can be ensiled with very different dry matter levels and kernel ratios. High yield per cultivated area and the expected nutritional value of the silage attainable when correct ensiling principles are applied, are the primary criteria for selecting the corn to be used in silage production (Dehpouri et al., 2022; Khan et al., 2014; Kung et al., 2018). Good digestibility of corn silage is ensured by a high carbohydrate, low crude ash and low crude fiber content, coming from a favorable kernel to cobb ratio (Szymańska et al., 2018). The resulting voluminous silage will have a high energy value (Horst et al., 2021; Zhang et al., 2018).

Accurate knowledge of chemical nutrient components of the feed ingredients is essential for formulating rations that meet the nutritional requirements of animals, feeding them a balanced ration with rich nutritional value, and ensuring efficient, economical and sustainable production (Motta et al., 2020; Schmidt et al., 2015; Zicarelli et al., 2023). Studies conducted in various parts of the world to evaluate the quality of corn silage, which is an important forage source in ruminant feeding are frequently encountered in literature, and it is possible to see therefrom that the nutrient content varies depending on the regions (Bernardes et al., 2018; Neumann et al., 2024; Szymańska et al., 2018; Venslovas et al., 2021; Zhao et al., 2022; Zicarelli et al., 2023). Besides the fact that corn is the most commonly ensiled forage crop in Turkey, the increase in silage corn acreage has also contributed to the rise in the share of corn among all forage crops. Silage corn production has a 46% share in the total forage production of the country (Koç and Çalışkan, 2016). According to Turkish Statistics Institute (TUIK, 2024) data, corn production in Turkey reached a new record of 9 million tons and the feed industry uses 88.5% of the whole crop. Konya province ranks first in the nationwide production with a share of 22.7%.

The use of high quality forages, such as corn silage, in ration formulations for ruminants guarantees animal welfare and the quality of animal products by enhancing ruminal fermentation (Cavaliere et al., 2018; Mastellone et al., 2022; Musco et al., 2020; Serrapica et al., 2020). A good nutrient density in dry matter is the decisive factor in ensuring high milk yield without compromising milk quality (García-Chávez et al., 2022).

As to Near Infrared Spectroscopy (NIRS) technology, it is already becoming a recommended method for enterprises engaged in animal production, as it offers many advantages such as being a rapid, practical and low-cost tool for the evaluation of feeds and silages (Evangelista et al., 2021; Zicarelli et al., 2023).

The aim of this study was to determine the nutritional values of corn silage samples collected from selected provinces in Turkey with a view to comparing the differences between them. The hypothesis was that accurate field knowledge of the nutritional properties of corn silages could contribute to improving balanced ration formulations, animal welfare and production efficiency.

MATERIAL AND METHOD

A total of 216 corn silage samples were collected from independent dairy cattle farms operating in 6 provinces including Aksaray (n=11), Balıkesir (n=14), İzmir (n=17), Kırşehir (n=14), Konya (n=47) and Niğde (n=113) between January 4th and December 26th, 2023. These samples were collected from ten different points on the silage front following a zig-zag pattern, mixed to obtain an aggregate sample, and finally a representative sample of 1.0-1.5 kg (dry matter) was formed taking handfuls of silage from several points of the evenly spread aggregate sample (Figure 1).

The samples were then placed in plastic zipper bags, compacted to remove the air, sealed air-tight, labeled

with date, location and sample name, and brought to Trouw Nutrition Türkiye Ankara head office. The samples were analyzed for crude ash (CA), crude protein (CP), ether extract (EE), crude cellulose (CC), starch, Neutral detergent fiber (NDF), Acid detergent fiber (ADF) and moisture using NIRS (Near Infrared spectroscopy (reflectance)) method.

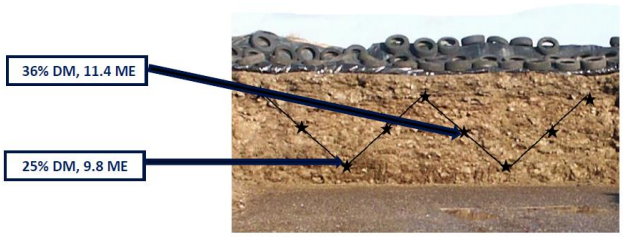

Figure 1. Sample collection pattern on the corn silage front.

NIRS is a system whereby infrared rays of a determined wavelength are projected on the sample through a monochromator and numerical data for each parameter are transferred to the computer through the detector. NIRS use to determine feed analysis, the authenticity of various nutritional properties (Graham et al., 2012). It's provides an opportunity to determine the chemical composition of feedstuffs. Apart from its rapidity, NIRS is a physical non-destructive method, requiring minimal sample preparation, with high accuracy. In contrast to traditional chemical analyses, NIRS requires no reagents, producing no waste. It is furthermore a multi-analytical technique as several determinations can be made simultaneously and once the NIRS is calibrated, it is simple to use and operate (Rahman et al., 2015).

Statistical analysis: Variance analysis was applied to determine whether there was a difference between provinces in terms of nutrient compositions of corn silages. Additionally, Duncan's multiple comparison test was used to determine the differences between provinces in terms of the nutrients found to be significant (SPSS, 2008). The following mathematical model was used for variance analysis:

$$y_{ij} = \mu + a_i + e_{ij}$$

y_{ij}: Measured value for any characteristic

μ: Expected average for the analyzed characteristic

a_i: i. Province effect (i= Aksaray, Balıkesir, İzmir, Kırşehir, Konya, Niğde)

e_{ij}: Normally distributed error effect with a mean of zero and variance of σ_e^2

RESULTS

The mean crude nutrient values of a total of 216 corn silage samples collected from 6 provinces subject to the study are shown in Table 1. Upon a general evaluation of the mean nutrient values, it is noteworthy that the coefficient of variation (CV), which is the ratio of the standard deviation to the mean, is high for starch. Starch value ranged from 5 g/kg at the lowest to 122 g/kg at the highest.

Table 1. Mean crude nutrient values of corn silages (g/kg).

Nutrient	N	Mean	SEM*	SD**	CV	Min.	Max.
CA	216	15.5	0.1	2.1	13.5	11	21
CP	216	21.2	0.2	3.3	15.4	13	32
EE	216	7.3	0.1	1.5	20.8	3	12
CC	216	64.6	0.3	4.3	6.7	54	77
Starch	216	58.0	1.9	27.6	47.7	5	122
NDF	216	135.6	0.6	8.3	6.2	115	161
ADF	216	79.0	0.5	6.7	8.5	61	93
Moisture	216	722.1	2.1	30.2	4.2	638	781

*SEM: Standard Error of the mean, **SD: Standard deviation.

According to the variance analysis, the differences between the provinces in terms of all nutrient compositions of corn silages were found to be statistically significant (P<0.01) as shown in Tables 2 and 3.

The lowest moisture contents were 699.6 and 702.2 g/kg in Balıkesir and Kırşehir respectively, whereas the highest was found in Konya with 730.0 g/kg. The differences between these provinces with high and low moisture contents were significant (P<0.01). Aksaray, Izmir and Niğde fell in between these two groups and the differences between them and other provinces were not statistically significant (P>0.05).

The highest CC content was found in Aksaray with 68.6 g/kg. While the differences between the silage samples from İzmir, Kırşehir, Konya and Niğde were not significant in terms of CC, the differences between those provinces and Aksaray, which was the highest of all, were significant (P<0.01). As to the silage samples from Balıkesir, they were between the high and low groups.

The lowest ADF content among all corn silage samples was found in Konya with 75.9 g/kg, whilst the highest was observed in Balıkesir and Kırşehir. The ADF differences between these two provinces were not significant, but the difference between the two high ADF provinces and the lowest province Konya was significant (P<0.01). Aksaray, İzmir and Niğde ranked in between the high and low ADF groups.

The lowest NDF contents in corn silage were found in Konya (132.2 g/kg), İzmir (133.9 g/kg) and Kırşehir (134.7 g/kg), whereas the highest was in Aksaray

(143.5 g/kg). While the difference between İzmir, Kırşehir and Konya was not significant, the difference between these provinces and Aksaray was significant (P<0.01). Balıkesir and Niğde ranked in between the high and low NDF groups.

Table 2. Multiple comparison test of means & standard errors for moisture, CC, ADF and NDF (g/kg)

		Moisture	CC	ADF	NDF
Province	n	$\bar{X} \pm S_{\bar{X}}$	$\bar{X} \pm S_{\bar{X}}$	$\bar{X} \pm S_{\bar{X}}$	$\bar{X} \pm S_{\bar{X}}$
Aksaray	11	714.7±8.8 ^{ab}	68.6±1.3 ^{a}	80.1±2.0 ^{ab}	143.5±2.4 ^{a}
Balıkesir	14	699.6±7.8 ^{b}	66.1±1.1 ^{ab}	82.5±1.7 ^{a}	137.3±2.2 ^{ab}
İzmir	17	720.9±7.1 ^{ab}	63.1±1.0 ^{b}	80.5±1.6 ^{ab}	133.9±2.0 ^{b}
Kırşehir	14	702.2±7.8 ^{b}	64.0±1.1 ^{b}	81.6±1.7 ^{a}	134.7±2.2 ^{b}
Konya	47	730.0±4.3 ^{a}	63.4±0.6 ^{b}	75.9±0.9 ^{b}	132.2±1.2 ^{b}
Niğde	113	725.0±2.8 ^{ab}	64.8±0.4 ^{b}	79.1±0.6 ^{ab}	136.4±0.8 ^{ab}

**P<0.01 the difference between means with different superscript for the same item is significant.

The lowest CP content was found in Niğde (20.2 g/kg) and the highest in Aksaray (25.0 g/kg) with a significant difference (P<0.01). Balıkesir, İzmir and Kırşehir were found to be within the average of these two provinces.

Aksaray, Konya and Niğde had the lowest EE content, while Balıkesir had the highest average with 8.9 g/kg (P<0.01). İzmir was similar to the low group with 7.6 g/kg and Kırşehir was aligned with the high group with 8.6 g/kg.

The provinces with the lowest starch averages were Aksaray (45.6 g/kg), Konya (52.9 g/kg) and Niğde (53.9 g/kg), whereas Balıkesir (84.3 g/kg) and Kırşehir (80.9 g/kg) were the ones with the highest averages and the difference between the provinces with low and high averages was significant (P<0.01). İzmir was found to be similar to both groups.

Aksaray had the highest average crude ash (CA) value with 17.6 g/kg. The CA differences observed between all other provinces were not significant, but the differences between those and Aksaray were significant (P<0.01).

Table 3. Multiple comparison test of means & standard errors for CP, EE, Starch and CA (g/kg)

		CP	EE	Starch	CA
Şehir	n	$\bar{X} \pm S_{\bar{X}}$	$\bar{X} \pm S_{\bar{X}}$	$\bar{X} \pm S_{\bar{X}}$	$\bar{X} \pm S_{\bar{X}}$
Aksaray	11	25.0±0.9 ^{a}	7.1±0.4 ^{c}	45.6±7.8 ^{b}	17.6±0.6 ^{a}
Balıkesir	14	22.6±0.8 ^{abc}	8.9±0.4 ^{a}	84.3±6.9 ^{a}	15.3±0.5 ^{b}
İzmir	17	23.1±0.7 ^{ab}	7.6±0.3 ^{bc}	66.7±6.3 ^{ab}	15.8±0.5 ^{b}
Kırşehir	14	22.7±0.8 ^{abc}	8.6±0.4 ^{ab}	80.9±6.9 ^{a}	15.6±0.5 ^{b}
Konya	47	21.4±0.4 ^{bc}	7.4±0.2 ^{c}	52.9±3.8 ^{b}	14.7±0.3 ^{b}
Niğde	113	20.2±0.3 ^{c}	6.9±0.1 ^{c}	53.9±2.4 ^{b}	15.7±0.2 ^{b}

P<0.01 the difference between means with different superscript for the same item is significant.

DISCUSSION

The nutritional value of corn silages is affected by several factors such as genotype, type of grain, agronomic characteristics (tillage, fertilization, etc.), climate (rainfall, temperature) and growing conditions, maturity at harvest, cut height and ensiling techniques (Khan et al., 2012; Khan et al., 2015). Furthermore, it has been reported that silage DM ratios vary depending on different corn varieties and significant nutrient differences exist across varieties (Öztürk and Çarpıcı, 2019).

According to the results of the present study, the silages with the lowest moisture content were from Balıkesir and the highest moisture ones originated from Konya, ranging from 28.53 to 30.04% across the 6 provinces surveyed. Although these values were slightly higher than the DM levels reported as 24.20% before and 25.07% after ensiling in Tekirdag (Erten and Koç, 2023), they were consistent with the DM ranges reported as 26.06-34.65% in Balıkesir (Kobak and Taş, 2024) and 25.58%-31.46% in Bursa (Öztürk and Çarpıcı, 2019). In addition, silage samples from Balıkesir and Kırşehir were the ones which had the lowest moisture content whilst presenting the highest ADF. Inversely, the highest moisture and lowest ADF contents were found in silage samples from Konya. This finding may be attributed to the climatic conditions in the province of origin, harvest time and nutrient composition differences in the maturity level at harvest. In a study conducted to determine the nutritional properties of maize silage produced in the Campania region of Italy, it was reported that one of the most important parameters that can affect the nutritional content of corn silage is the moisture level at harvest, and in silages produced in the Piana del Sele zone, high grain percentage led to an increase in structural carbohydrates despite the decrease in dry matter (Zicarelli et al., 2023). Depending on various factors such as soil fertility, climate of the region and yield per acre, most of the structural carbohydrates in the feed ration come from corn silage (Borreani et al., 2013). However, it is known that the nutritional value of feeds decline as the proportion of

structural carbohydrates increases (Grant et al., 2014). In the present study, the total structural carbohydrate (CC, ADF, NDF) averages of corn silages were 17.72% higher than the total averages of other crude nutrients (CA, CP, EE, starch). Again, when the average values were considered, the structural carbohydrates, especially the average NDF was found to be 13.56% in silages having 27.79% DM. On the basis of the provinces, the highest CC and NDF contents were found in Aksaray and the highest ADF contents were found in Balıkesir and Kırşehir. However, corn silages from these provinces had relatively higher DM contents. In general, it can be stated that structural carbohydrate contents are related to the DM content of the silage, which in turn depends on factors such as climatic conditions (increasing temperatures and decreasing rainfall), changes in rainfall distribution throughout the year or harvest time that might have affected the nutrient content of the grain. It is also underlined that corn is a forage crop particularly sensitive to water stress (Tubiello et al., 2000).

Table 3 shows that CP contents of corn silages ranged between 20.2 g/kg and 25.0 g/kg, the lowest being in Niğde and the highest in Aksaray, with an average of 21.2 g/kg. In another way of expression, it was observed that corn silage with an average of 27.79% DM had a CP average of 7.62%. This value is within the normal limits for corn silage and is consistent with the average 7.8% CP content expected in a good quality silage (Keleş and Çıbık 2014). Similarly, Kobak and Taş (2024) reported that in Balıkesir's Manyas county climatic conditions and clay-loam soil, the CP content of corn silages varied between 6.09-8.25%. It has been suggested that the differences between CP levels were due to corn varieties, nitrogen levels or vegetation stage during ensiling (Başaran et al., 2017; Koç and Çalışkan, 2016; Öztürk and Çarpıcı, 2019).

The decrease in CP content can be explained by starch and fiber accumulation in corn DM, and CP content is proportional to soil uptake (Kolar et al., 2022). It has been suggested that as the corn grain matures, DM and starch content increases in line with its density, while NDF and CP contents decrease (Khan et al., 2015). The increase in NDF and CP contents at the expense of starch in corn silage samples from Aksaray, and similarly, the finding of low DM and starch content with high NDF in Kırşehir are consistent with this view.

Unlike what was reported by Zhao et al., (2022), it can be said that in the present study there is a positive correlation between DM yield and EE content of corn silage, as both DM and EE contents were found to be higher in Balıkesir and Kırşehir compared to other provinces. On the other hand, it has been reported that EE contents may fluctuate depending on the planted corn variety (Ettle and Schwarz, 2003). The statistical differences found in EE contents in the samples collected from 6 provinces may be connected with this.

The lowest mean starch values of corn silages were found in Aksaray, Konya and Niğde, and the highest in Balıkesir and Kırşehir. Energy, which constitutes the main source of metabolizable energy in corn silage, comes from starch in the grain and is considered one of the most important parameters (García-Chávez et al., 2022; Khan et al., 2015). Particularly for the corn silage, the starch content is determined by the grain ratio and the maturity of the plant. Maturity, in its turn determines the starch level of the corn grain, which constitutes 70-75% of the dry weight (Zicarelli et al., 2023). In their study conducted under dryland conditions, Bernardes et al., (2018) emphasized the importance of the starting time of harvest, as well as the cut height, indicating that at a cutting height of 30 cm, the starch content of corn silage increased from 28.2% to 33.8%. In the present study, the average starch content was 20.87%. In terms of individual provinces, this value was calculated as 15.98% for Aksaray, 28.06% for Balıkesir, 23.89% for İzmir, 27.16% for Kırşehir, 19.59% for Konya and 19.6% for Niğde. These results were not consistent with the literature, which reported that the average starch content should not be less than 35% (Ferraretto et al., 2018). However, the findings from Balıkesir and Kırşehir are in line with the results of studies reporting that the target starch range for a good quality corn silage should be 25-35% (Keleş and Çıbık, 2014). Silage samples collected from 4 provinces, namely Aksaray, Izmir, Konya and Niğde, had less than 25% starch. This lower starch content can be attributed to several reasons such as insufficient grain formation due to high temperatures especially in August and September in recent years, high proportion of cobs in the wholecrop to be ensiled in the region, and early harvesting. In that study it was determined that the highest CA of the surveyed corn silages was in Aksaray. The probable explanations of this finding were reported as the anionic-cationic mineral composition of the local soil due to its proximity to Lake Tuz (a salt lake), the mineral density of the fields (Uzbilek and Qaranjıkı, 2020) and its implications on the crops. Besides, high crude ash content in the silage is an indication of possible contamination with soil or other impurities (Kolar et al., 2022).

AND CONCLUSION

In this study, 216 corn silage samples collected from six different provinces were evaluated and it was concluded that corn silages produced in those provinces may present variable chemical crude nutrient compositions. The cause of this variability in corn silage quality was probably the climatic conditions under which the corn crop was grown and their effect on grain density,

environment and soil characteristics of the production region, variety of corn, harvest times and specific zone. However, it would be opportune to suggest that more nutritional quality studies be carried out, expanding the regional diversity. Additionally, it can be reiterated that NIRS technology, which is a rapid and practical control analysis tool can help in improving the feeding plan.

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