ISPEC Tarım Bilimleri Dergisi, 8(3): 638-646, 2024
ISPEC Journal of Agricultural Sciences, 8(3): 638-646, 2024
DOI: https://doi.org/10.5281/zenodo.12607765

Effect of Adding Different Ratios of Oat (*Avena sativa* L.) Cracks on the Silage Quality of Fodder Pea (*Pisum arvense* L.)

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Abstract

Silage is an optimal method for preserving high-quality forage and forage legumes are vital feed resources for ruminants and can be utilized in various forms, including hay, silage, and grazing. The fodder peas is a versatile crop, utilized for grain production, herbage, hay, pasture, green manure, and silage, either as a monoculture or in combination with cereals. Feeds such as fodder peas, characterized by high levels of crude protein, mineral content, and buffering capacity, but low levels of water-soluble carbohydrates, require the addition of specific additives to enhance silage fermentation. The research was conducted to determine the effect of the cracked oat grains on fodder peas silage quality. Fresh fodder peas was harvested at full-bloom stage and ensiled with 3 %, 6 % 9 % and 12 % added cracked oat grains in plastic bags for 45 days. The crude protein (%), crude ash (%), ADF (%), NDF (%), P (%), K (%), Ca (%), Mg (%), digestible dry matter (DDM) (%), dry matter intake (DMI) (%), total digestible nutrients (TDN), net energy-lactation (NEl), net energy-maintenance (NEm), net energy-gain (NEg), fleig score, and relative feed value (RFV) were determined. The dry matter of ensiled fodder peas and cracked oat grain added fodder peas silage varied between 38.30-39.54%. The pH values were between 4.15-4.50 in silage of fodder peas and cracked oat grain added fodder peas silages. Fleig score values were varied between 101.47-118.21. According to the Fleig scores, adding 12% cracked oat grains to fodder peas during siloing may be recommended to obtain silage.

Research Article

Article History
Received :16.04.2024
Accepted :25.05.2024

Keywords
Fodder pea
silage
cracked oat grain
silage quality

1. Introduction

Grazing is widely recognized as the most cost-effective method of feeding livestock. In many regions, seasonal changes and shortages significantly limit the productivity of rangelands, necessitating alternative strategies for ensuring a consistent feed supply. The limited range and low yield levels of pastures underscore the importance of silage production, which is considered the closest alternative to fresh forage in terms of nutritional quality (Ates and Tenikecier, 2022). Silage is an optimal method for preserving high-quality forage, particularly during periods when fresh forage is unavailable (Burgu and Mut, 2023). It is harvested during specific periods and subsequently fermented in an anaerobic environment, which is critical for producing a stable and nutritious feed resource (Ates and Tenikecier, 2022). Considering that there is a positive relationship between nutrition and the productivity of ruminant animals, nutrient content and other quality characteristics of feeds are of great importance for animal productivity (Kızılşimşek et al., 2023).

Forage legumes play a multifaceted role in agriculture, serving not only as forage and silage but also as food, ornamental plants, soil improvers, and sources of pollen and nectar. Among these, annual forage legumes are especially significant as a major nutrient source for livestock and are cultivated globally for this purpose (Ates et al., 2010). These legumes are vital feed resources for ruminants and can be utilized in various forms, including hay, silage, and grazing (Fernandes et al., 2013). Fodder pea (*Pisum arvense* L.), commonly referred to as "field pea," "forage pea," "winter pea," "grey pea," and "Austrian winter pea," holds significant global importance as a forage legume. This species is an annual forage legume that is grown in the cool-season (Sayar and Han, 2016) and is extensively cultivated in semi-arid regions where annual precipitation ranges from 350 to 650 mm, such as in Anatolia and the Mediterranean area. Fodder pea exhibits optimal performance on fertile, well-drained soils with high moisture-holding capacity. It thrives best on loam, silt loam, and well-textured soils with a pH range of 6.0-7.5 (Ateş, 2012). The fodder peas is a versatile crop, utilized for various purposes including grain production, herbage, hay, pasture, green manure, and silage, either as a monoculture or in combination with cereals. Additionally, it serves as a cover crop and rotational crop (Ates and Tenikecier, 2020). The crop is notable for its high-quality protein content. Although fodder peas's levels of cell-wall components are lower compared to grasses, its cell walls are highly lignified (Servet and Ate, 2004).

Feeds such as fodder peas, characterized by high levels of crude protein, mineral content, and buffering capacity (McDonald et al., 1991; Rooke and Hatfield, 2003; Gümüştaş and Turan, 2022), but low levels of water-soluble carbohydrates (Borreani et al., 2006), require the addition of specific additives to enhance silage fermentation (Rooke and Hatfield, 2003; Kaiser, 2004; Ni et al., 2017). To enhance the nutrient content of silages used as roughage, various additives are commonly employed. Notably, carbohydrate sources that act as fermentation stimulants are particularly important among these additives (Kaiser, 2004). These include corn, barley, urea, molasses, and acids such as hydrochloric acid, propionic acid, phosphoric acid, lactic acid, and formic acid to create an acidic environment. Additionally, lactic acid-producing bacterial cultures and enzymes are utilized to facilitate fermentation (Kılıç et al., 2000; Touno et al., 2014). Weiss and Underwood (2009) stated that grain added forages at ensiling are more complete feeds, and adding 45-90 kg/wet ton cracked or rolled grains to forages at ensiling increases dry matter by up to 5 points. The application of cereal grains or citrus, beet pulps to low-DM forages was improved the fermentation characteristics of the silages, and the amount of effluent reduce determined (Jones et al., 1990; Jacobs et al., 1995).

For fodder and silage production, fodder peas is grown in mixtures with cereals in different ratios, but also for the silage from the pure fodder peas using additives. Besides, many livestock breeders also ask whether oat (*Avena sativa* L.) grains can be added to fodder peas silage and in what quantity. In order to answer this question, this study was carried out to determine the effect of crushed oat grains on the quality of pure fodder peas silage.

2. Materials and Methods

2.1 Experimental site

In November 2022, a basal fertilizer containing nitrogen (N) and phosphorus (P) at a rate of 50 kg per hectare was incorporated into the soil during land preparation on a 5-hectare farmer's field located in Gazioğlu, Süleymanpaşa-Tekirdağ, Türkiye.

2.2 Plant material

The seeds of the fodder peas variety 'Töre' were sown using a seed drill at a rate of 120 kilograms per hectare with a row spacing of 25 centimeters (Ates and Tenikecier, 2020). Fresh samples were taken at the full-bloom stage at a height of 3 cm above the ground (Tenikecier and Ates, 2021). Grains of oat variety 'Sebat' were subjected to a mechanical cracking process.

2.3 Ensiling process

The samples were left to wither for 2 hours and then approximately 1.5-2 cm chopped by mechanically (Er and Mut, 2023). 100 g withered fodder pea sample without additives and 100 g withered fodder pea sample with 3 g, 6 g, 9 g and 12 g cracked oat (Weiss and Underwood, 2009) were vacuumed (İleri et al., 2022) in to the 20x26 cm plastic bags and were stored in a dark environment for a period of 45 days to facilitate fermentation at ambient temperatures ranging from 15 to 28°C (Jia et al., 2021). After 45 days, the pH of the silages was measured using a pH meter. The research was conducted in complete randomized split-plot design with four replications.

2.4 Chemical analysis

It is well-documented that oven drying feed samples at temperatures exceeding 60 °C can result in heat-damaged protein and increased values of fiber and lignin. Furthermore, oven drying feedstuffs containing proanthocyanidins, even at temperatures below 60°C, has been shown to increase neutral detergent fiber (NDF), fiber-bound nitrogen, and lignin content (Reed and Van Soest, 1984). To determine the dry matter content, the matured silage samples were dried to a constant weight in an air oven at 60°C for 48 hours, followed by a subsequent day of storage at ambient temperature. The samples were then ground to small pieces (≤1 mm) and utilized for analysis. Nitrogen (N) content was analyzed following the procedures outlined by the Association of Official Analytical Chemists (AOAC, 2019). The crude protein content (%) was calculated by multiplying the nitrogen content by a factor of 6.25. The samples were wet-digested with a nitric-perchloric acid mixture, and phosphorus (P, %) content was determined spectrophotometrically. The potassium (K, %), calcium (Ca, %), and magnesium (Mg, %) contents were quantified using an inductively coupled plasma-optical emission spectrometer (ICP-OES) (Isaac and Johnson JR, 1998). Crude ash (%), acid detergent fiber (ADF, %), and NDF (%) contents were determined using Weende and Van Soest methodologies (AOAC, 2019; Van Soest et al., 1991). All analyses were conducted in duplicate. The digestible dry matter (%), dry matter intake (%), relative feed value (%), total digestible nutrients (TDN), net energy for lactation (NEl), net energy for maintenance (NEm), and net energy for gain (NEg) were calculated using established equations for forage evaluation (Schroeder, 1994). Fleig score was calculated using the formula suggested by Kılıç (2010), which was given below;

Fleig Score = 220 + (2 x % DM - 15) - 40 x pH

2.5 Statistical analysis

All data was performed using analysis of variance (ANOVA) with TARIST software (Açıkgöz et al., 1994), and treatment means were compared using the least significant difference (LSD) test, implemented with MSTAT-C software (Düzgüneş et al., 1987).

3. Results and Discussion

The results of the cracked oat grains added fodder peas silage are given in Table 1, 2 and 3. The dry matter, pH, crude protein, crude ash, ADF, NDF, P, K, Ca, Mg, TDN, DDM, DMI, Fleig Score and relative feed value means were statistically significant (P<0.01). There were no statistically significant difference between means of NEl, NEm, NEg (P>0.05) (Table 1, 2 and 3). Dry matter serves as an indicator of the nutrient content available to animals in a given feed. Livestock require a specific daily intake of dry matter to sustain health and maintain production levels (CCOF, 2020). The dry matter of ensiled fodder peas and cracked oat grain added fodder peas silage varied between 38.30-39.54% (Table 1).

Table 1. Dry matter, pH, Crude protein, ADF and NDF of ensiled fodder peas

	Dry Matter	pH	Crude Protein	Crude Ash	ADF	NDF
Fodder Pea	38.30b	4.50a	19.78a	3.52d	27.05e	38.05d
Fodder Pea+3% cracked oat	39.53a	4.31b	17.49e	3.95c	27.59d	39.10c
Fodder Pea+6% cracked oat	39.15a	4.23bc	17.81d	4.10b	27.69c	39.15c
Fodder Pea+9% cracked oat	39.48a	4.34b	18.06c	4.20b	27.80b	39.23b
Fodder Pea+12% cracked oat	39.54a	4.15c	18.13b	4.66a	27.97a	39.29a
Mean	39.20	4.31	18.25	4.09	27.62	38.96
LSD	0.482**	0.160**	0.047**	0.097**	0.048**	0.051**

The lowest dry matter (38.30 %) was determined in pure fodder peas silage and the highest were determined in fodder peas+3% cracked oat (39.53 %), fodder peas+6% cracked oat (39.15 %), fodder peas+9% cracked oat (39.48 %) and fodder peas+12% cracked oat (39.54 %) silages. The dry matter increasing with adding cracked oat to fodder pea silage was compatible to Weiss and Underwood (2009). Heuze et al. (2017) reported that the crude protein and digestibility ratios decrease when the dry matter ratio increase. İleri et al. (2022) also indicated that silage fermentation is delayed and quality is reduced under low carbohydrate conditions.

The PH was statistically significant according to P<0.01. The pH values were between 4.15-4.50 in silage of fodder peas and cracked oat grain added fodder peas silages (Table 1). While the highest pH was determined in fodder peas silage (4.50), the lowest was determined in fodder peas+12 % cracked oat (4.15) silage. Jacobs et al. (1995) reported that adding barley grains to pasture silage at ensiling decreases pH. Geren (2001), Silva et al. (2015), Heuze et al., (2017) and İleri et al. (2022) reported that the similar pH values for the silage corn that have 25-35% dry matter ratio. Limin Kung et al. (2003), Jian et al. (2017), Ni et al. (2017) declared adding molasses to silages and Canbolat et al. (2019) adding molasses to fodder peas silage was decreased pH.

The highest crude protein was obtained from fodder peas silage (19.78 %) and the lowest was in fodder peas + 3 % cracked oat silage (17.49 %) (Table 1). Oat grains usually contain 11-14 percent crude protein. Besides, crude fiber content of oats is usually 11 percent or higher, compared to 2 percent for grains that thresh free of hulls (Boyles and Johnson, 2024). As the hull ratio increased with the addition of different amounts of oat cracks, a change in fiber and protein ratio occurred. The highest ADF (27.97 %) and NDF (39.29 %) values were determined in fodder peas+12 % cracked oat silage and the lowest values were in fodder peas silage. Rohweder et al. (1978) determined best quality feed has to be with 41 % ADF and 53 % NDF content to have greater than 151 RFV. Pahlow et al. (2002) stated that using silage additives is generally advisable for forage legumes, for protein protection and to improve fermentation quality. Turgut et al. (2005) and İleri et al. (2020) reported that the significant relations between silage and silage material in terms of NDF and ADF contents. The results of our analysis of NDF and ADF contents were found to be consistent with those of previous studies (Geren, 2001; Azevedo et al., 2011; Silva et al., 2015; Heuze et al., 2017; Kızılşimşek et al., 2023).

Maintaining a balanced mineral intake is crucial for the health and well-being of animals. Each mineral serves specific functions in the body, and deficiencies cannot be compensated for by other minerals. For instance, Ca and P are intricately linked to animal metabolism and overall health. It's imperative to maintain the proper ratio of Ca and P in conjunction with vitamin D, as highlighted by Ates and Tekeli (2005). The skeletal system holds a significant portion of Mg, comprising approximately 68-73 % of the total Mg content in an animal's body. Additionally, the presence of P in the rumen is vital, as higher levels of P promote Mg absorption. In instances where animals graze on phosphorus-deficient pastures, the rumen may have low concentrations of P, further hindering Mg absorption. Moreover, the Ca levels in the blood also influence these processes (Ates, 2017). An analysis of variance indicated that there were statistically significant differences in macro elements among fodder pea and cracked oat added fodder pea silages (P<0.01). The highest P (0.36 %), K (2.03 %), Ca (1.23 %) and Mg (0.37 %). contents were determined in fodder peas + % 3 cracked oat silage (Table 2). The lowest P content was determined in fodder peas silage (0.31 %). The lowest K (1.80 %) and Ca (1.00 %) contents were determined in fodder peas+12 % cracked oat silage. The lowest Mg contents were determined in fodder peas + 9 % cracked oat (0.32 %) and fodder peas + 12 % cracked oat (0.31 %) silages. The highest TDN was determined in fodder peas silage (65.42) and the lowest in fodder peas + 12 % cracked oat silage (64.18) (Table 2). The DDM and DMI of ensiled fodder peas and cracked oat grain added fodder peas silages were varied between 67.11-67.83 and 3.05-3.15 respectively (Table 2 and 3).

Table 2. P, K, Ca, Mg contents, TDN and DDM of ensiled fodder peas

	P	K	Ca	Mg	TDN	DDM
Fodder Pea	0.31e	1.99b	1.19b	0.36ab	65.42a	67.83a
Fodder Pea+3% cracked oat	0.36a	2.03a	1.23a	0.37a	64.62b	67.40b
Fodder Pea+6% cracked oat	0.35b	1.96c	1.15c	0.35b	64.51b	67.33c
Fodder Pea+9% cracked oat	0.34c	1.92d	1.12d	0.32c	64.38bc	67.24d
Fodder Pea+12% cracked oat	0.32d	1.80e	1.00e	0.31c	64.18c	67.11e
Mean	0.34	1.94	1.14	0.34	64.62	67.38
LSD	0.005**	0.027**	0.016**	0.017**	0.298**	0.036**

Table 3. DMI, Nel, NEm, Neg, Fleig Score and Relative Feed Value of ensiled fodder peas

	DMI (%)	NEl	NEm	NEg	Fleig Score	RFV
Fodder Pea	3.15a	0.67	0.73	0.40	101.47c	165.83a
Fodder Pea+3% cracked oat	3.07b	0.67	0.72	0.39	111.31b	160.35b
Fodder Pea+6% cracked oat	3.06c	0.66	0.72	0.39	114.61ab	159.97c
Fodder Pea+9% cracked oat	3.06c	0.66	0.72	0.39	110.50b	159.44d
Fodder Pea+12% cracked oat	3.05d	0.66	0.71	0.39	118.21a	158.89e
Mean	*3.08*	*0.66*	*0.72*	*0.39*	*111.22*	*160.90*
LSD	0.008**	ns	ns	ns	6.407**	0.153**

While the lowest DDM and DMI was determined in fodder peas + 12 % cracked oat silage, the highest were determined in fodder peas silage. The NEl, NEm and NEg values varied between 0.66-0.67, 0.71-0.73 and 0.39-0.40 respectively (P>0.05). DDM and DMI was higher than whom reported 63.47 % and 2.83 % (Seydoşoğlu, 2019).

One of the criteria considered in the determination of silage quality is pH value. In a good silage, there is a close relationship between pH value and Flieg score of silage (Kılıç, 2010; Er and Mut, 2023). Fleig score based silage quality was declared (<20 worthless, 20–39 satisfactory, 40–59 moderate, 60–84 good and 85–100 very good) by Kılıç (2006). Fleig score values were varied between 101.47-118.21. The lowest (101.47) Fleig score was determined in fodder peas silage and the highest (118.21) in fodder peas+12% cracked oat silage (Table 3). The determined Flieg scores are higher than the values determined by Demiroğlu Topçu and Kahya (2023) in berseem clover (*Trifolium alexandrinum* L.)-annual rye grass (*Lolium multiflorum* Lam.) mixture silages.

The relative feed value index is a measure of the quality of a given fodder. As the RFV of a given fodder decreases, its quality also decreases (Önal Aşçı and Acar, 2018). The relative feed values were varied between 158.89-165.83. The lowest was obtained from fodder peas+12% cracked oat silage and the highest from fodder peas silage (Table 3). The relative feed values were opposite to the reports of Canbolat et al. (2019), who reported that the values increased when molasses was added to the fodder peas silage.

4. Conclusions

Legume forages and their silage, has leading roles with their high protein, macro and micro nutrients relative feed values and low crude ash, ADF, NDF contents rather than grasses and cereals in livestock fed. This was corroborated by the findings of the study. However, it was found that incorporating cracked oats into fodder peas improved silage fermentation. The research results not only showed increases in dry matter, crude ash, ADF, and NDF, but also in Fleig score with the addition of cracked oats to fodder peas silages. According to the Fleig scores, adding 12 % cracked oat grains to fodder peas during siloing may be recommended to obtain silage.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

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To Cite	Tenikeciler, H.S., Ateş, E., 2024. Effect of Adding Different Ratios of Oat (*Avena sativa* L.) Cracks on the Silage Quality of Fodder Pea (*Pisum arvense* L.). *ISPEC Journal of Agricultural Sciences*, 8(3): 638-646. DOI: https://doi.org/10.5281/zenodo.12607765.