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Research Article

The impact of molasses and inoculant on the silage quality of triticale and forage pea mixtures at different ratios

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ABSTRACT

The objective of this study was to investigate the effects of inoculant and molasses additives on the fermentation quality, nutrient content and digestibility of silages prepared with varying percentage proportions of triticale and forage pea. In the study, triticale mixtures with 20%, 40%, 60%, and 80% forage pea were utilized, and silage materials were prepared by adding molasses and inoculant to these mixtures. This procedure was repeated to create a total of 48 groups. These groups consisted of a control group, a group treated with 5% molasses, and a group treated with 10 g/t inoculant (1.25×10^{11} CFU/g). In line with practical agronomic conditions, pure stands were not evaluated, as mixtures are generally more relevant for field applications. The findings demonstrate that an increase in the ratio of forage pea resulted in enhanced lactic acid production and notable improvements in digestibility and metabolic energy values. Among the silage mixtures, the highest digestibility and energy values were observed in those containing 80% forage pea. The molasses additive demonstrated more pronounced effects on digestibility and energy values than the inoculant. However, high pea ratios (60% and 80%) resulted in unfavorable outcomes for certain fermentation parameters, particularly in terms of the FLIEG values. The findings of the study elucidate the impact of molasses and inoculant additives on the quality of silages prepared with varying proportions of triticale and forage pea mixtures.

Keywords: Forage pea, Inoculant, Molasses, Silage quality, Triticale

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Introduction

As a result of the increasing demand for animal food in parallel with the growing human population, the number of animals increased (40), but there was no change in the feed resources and pasture rates (33). At this stage, the sustainability of animal feed production necessitates the development of alternative feed sources and improved storage methods. Silage, which has an important role in ruminant nutrition, can be prepared using various parts of plants, including stems, leaves, grains, and by-products such as husks and cobs (23). Silage, which is prepared by lactic acid (LA) fermentation of various parts of plants, provides the preservation of feed nutrients (23, 26). There are many methods for the preparation of silage that allow quality roughage to be provided in all seasons (10, 17, 47). In addition to using different forms and shredding methods for the preparation of feed materials for silage, anaerobic stability, and high-quality silage can be achieved by adding various additives, such as bacterial inoculants, organic acids, enzymes, and absorbents (16, 17, 27).

Silage is a type of feed created by fermenting and storing high-moisture feeds, that has been widely used in animal nutrition for a long time (7). Plant materials and additives used in silage production directly affect the nutritional value, fermentation quality and microbial stability of silage. In recent years, research on different plant combinations and additives that can provide higher yields and improved quality in feed plants has increased (16, 17, 21, 27). In this context, triticale and feed pea mixtures are increasingly preferred in silage production. Triticale (× Triticosecale) is a cereal plant with high yield potential obtained by hybridizing wheat and rye.

Triticale's more durable structure and high energy content compared to other cereals make it especially attractive for ruminant animal nutrition (5, 7). However, using triticale silage alone may be insufficient in terms of protein content. This situation can be balanced by combining legumes such as forage pea (*Pisum sativum*), which is notable for its high protein content, with triticale. Forage pea provides an important source of nutrients in silage mixtures due to its high bioavailable protein and fiber content (6, 7).

As demonstrated in previous studies, pure stands of forage pea or triticale silages can be evaluated (6, 29). However, sole-crop forage pea silages often exhibit poor fermentation due to the plant's low dry matter content and limited buffering capacity, making the use of inoculant additives advisable (9, 12, 31, 44). Moreover, lodging is another challenge for forage pea, as it can sharply decrease dry matter levels and increase the risk of clostridial contamination (23, 34). To overcome these issues, cereal species used as companion crops or higher seeding rates have been recommended to reduce lodging and enhance ensiling success (12). Indeed, it is generally accepted that mixtures outperform monocultures in terms of forage yield, fermentation quality, and nutritive value (18, 25, 28). Mixing cereals into legume silages also improves dry matter and water-soluble carbohydrate contents, thereby supporting a healthier fermentation process (8, 36). Consequently, the present study was conceived with a focus on pea–triticale mixtures as opposed to 100% monocultures, with the objective of more accurately reflecting practical agronomic conditions and providing a realistic assessment of silage quality under field-relevant scenarios.

Inoculants and additives such as molasses, play a critical role in improving the fermentation process of silage quality. Inoculants usually contain LA bacteria (LAB) and help to decrease the pH by allowing the silage to ferment rapidly. This prevents the proliferation of unwanted pathogens and increases the microbial stability of silage (10, 17, 30, 37, 47). Inoculant applications provide significant benefits especially in silage materials with poor fermentation conditions. Molasses is an energy source with high sugar content; it increases the quality of silage by supporting LA production during the fermentation process (30). Additionally, molasses additive helps to rapidly form the desired fermentation products by shortening the fermentation period.

Many studies have shown that inoculant and molasses additives, when used alone or together, increase silage quality. For example, Kung Jr et al. (21) stated that bacterial inoculants increase LA production, lower pH and improve protein preservation. Molasses, as a sugar source, has been found to provide more effective LA production during the fermentation process (27). However, the effect of the combination of these two additives with different plant materials has not been fully elucidated. The combined use of inoculant and molasses additives with different plant materials is a subject that needs to be investigated in terms of silage fermentation parameters and nutritional values. The aim of the study was to investigate how triticale and forage pea mixtures interact with inoculant and molasses additives and the effects of these interactions on fermentation parameters and overall silage quality.

Materials and Methods

Trial Area and Material: The study was carried out in the trial area within the Kırıkkale University Campus. The experimental area was situated within the Kırıkkale University campus in Yahşihan province, located in the Central Anatolian region of Türkiye (39°53'04.9" N, 33°26'20.0" E). The region experiences hot and dry summer months and cold and rainy winter months, with an annual precipitation amount of 405 millimeters. However, in the year of the study, precipitation levels reached 414.3 millimeters. The soil of the study area is slightly alkaline (pH=7.73), salt-free (EC=0.10dS/m), moderately calcareous (12.15%), and low in phosphorus (3.13 ppm) level. The study area exhibited a low organic matter content (1.33%). While the potassium level (216 ppm) is sufficient, the nitrogen level (0.18%) is low. Triticale (TRI) and Forage pea (FP) species were planted in 5 × 1.5 m^2 plots with 3 replicates. The mixture ratios were determined and they were planted as 80% TRI+40% FP, 60% TRI+80% FP, 80% TRI+60% FP, and 40% TRI+80% FP. Harvesting was done manually from a 1 m^2 area of each plot**.**

Preparation and Analysis of Silage Material: Subsequent to the conclusion of the harvesting process, the sample materials collected from each mixture ratio were chopped to a length of 2–3 cm. For each mixture ratio (20%, 40%, 60%, and 80%), a total of 15 kg of silage was prepared. Following this, molasses and microbial inoculants were applied to the materials, and the mixture was thoroughly agitated to ensure homogeneity. Subsequently, approximately 800 g of silage from each mixture was manually compressed into 1-liter containers, with four replicates prepared for each treatment. The procedure yielded a total of 48 experimental units, comprising a control group, a group treated with 5% molasses, and a group treated with 10 g/t inoculant (1.25×10^{11} CFU/g). The inoculant used in this study was Inoculant® (Du Pont Pioneer), containing multiple strains of *Lactobacillus plantarum*: LP286 (DSM 4784, ATCC 53187) at 2.5×10^{10} CFU/g, LP318 (DSM 4785) at 5×10^{10} CFU/g, LP319 (DSM 4786) at 5×10^{10} CFU/g, and LP346 (DSM 4787, ATCC 55943) at 2.5×10^{10} CFU/g. In addition, *Enterococcus faecium* strains SF301 (DSM 4789) and SF202 (DSM 4788) were present at a concentration of 1.25×10^{10} CFU/g.

After ensiling, the jars were stored at 20–25 °C for 60 days. At the conclusion of this period, all silages were opened and subjected to a comprehensive physical analysis, chemical content analysis, fermentation parameter evaluation, in vitro digestibility determination, and energy level measurement. The silage samples were then opened and scored by three experts in accordance with the DLG standard for odor, color, and texture. Subsequently, 100 mL of distilled water was added to 25 g of fresh silage sample and mixed thoroughly with a mixer. The resulting liquid was then filtered. The pH value of the filtrate was determined by means of a digital pH meter (HANNA, HI 2221). The concentration of Ammonia-N in the silages was determined by the Kjeldahl distillation method, utilizing the same filtrate (3). The quantification of LA in the silage extracts was performed using a spectrophotometric procedure (38) adapted from the method of Barnett (4). The analysis of other organic acids, namely butyric acid (BA), propionic acid (PA), and acetic acid (AA), was carried out using a gas chromatography method modified from Tekin and Kara (38). The concentrations of organic acids were expressed in mmol/L, and their percentages on a dry matter (DM) basis were calculated after determining the DM content by air-drying the samples followed by oven-drying at 65 °C for 72 hours.

The crude protein (CP) and crude ash (CA) levels were determined in accordance with the methodology outlined by the AOAC (3). The organic matter (OM) level was calculated by subtracting the ash level from the DM level. Neutral detergent fiber (aNDFom) was analyzed according to the method of Van Soest and Robertson (41), using heat-stable α-amylase and expressed exclusive of residual ash (40). Acid detergent fiber (ADFom) was determined with the ANKOM® fiber analyzer following the procedure of Goering and Van Soest (13), with values expressed exclusive of residual ash. The in vitro dry matter digestibility (IVDMD) of the samples was determined in accordance with the methodology proposed by Tilley and Terry (39), with modifications introduced by Marten and Barnes (22). Twenty days before collecting rumen fluid, 3 Holstein cows with rumen cannulation were fed a ration containing 60% quality roughage and 40% concentrate. Three to four hours after morning feeding, rumen fluid was collected from the cannulated areas using a special catheter. Rumen fluid was quickly brought to the laboratory by placing it in a thermos at body temperature. The rumen fluid was then used as an inoculant to detect IVDMD, and was subsequently filtered through a four-layer cheesecloth. The metabolizable energy (ME, Mcal/kg) and lactation net energy values (NEL, Mcal/kg) of the samples were calculated using the following formulas:

ME, (Mcal/kg) = Digestible energy × 0.82

NEL, (Mcal/kg) = 0.00245 × TDN (Total Digestible Nutrient)-0.12.

To provide a baseline for evaluating silage quality, the chemical composition of the fresh forage pea and triticale was analyzed before ensiling (Table 1).

Table 1. Nutrient composition of fresh forages used in the experiment (g/kg DM unless otherwise stated)

Parameter	FP	TRI
DM (%)	24.91	45.33
CA	8.89	7.03
OM	91.11	92.97
CP	12.33	9.26
NDF	38.49	48.20
ADF	21.36	29.22

DM: Dry matter, CA: Crude ash, OM: Organic matter, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber. FP: Forage pea, TRI: Triticale.

In addition, the method of calculating FLIEG points from the DM and pH values of silages was as follows (37):

FLIEG Points = 220 + (2 x % DM - 15) - (40 x pH).

Accordingly, silage quality was evaluated on a scale of 0-20 (poor), 21-40 (intermediate), 41-60 (satisfactory), 61-80 (good), and 81-100 (very good).

Statistical Analysis: A two-way ANOVA was conducted to evaluate the effects of additive type (control, molasses, inoculant), forage pea inclusion level (20%, 40%, 60%, 80%), and their interaction on silage parameters. The GLM included the main effects of additive type (A), forage pea proportion (P), and their interaction (A×P). The model used was as follows:

$$Y_{ijk} = \mu + A_i + P_j + (A \times P)_{ij} + \varepsilon_{ijk}$$

where

- Y_{ijk} is the observed value for the kth replicate in the ith additive and jth pea proportion,
- μ is the overall mean,
- A_i is the fixed effect of the additive (i = 1, 2, 3),
- P_j is the fixed effect of forage pea proportion (j = 1, 2, 3, 4),
- $(A\times P)_{ij}$ is the interaction between additive and pea proportion, and
- ε_{ijk} is the residual error term.

Data normality and homogeneity of variance were tested using Shapiro–Wilk and Levene's tests, respectively. Where significant main or interaction effects were found ($P<0.05$), Tukey's HSD test was applied to identify pairwise differences. All statistical analyses were performed using IBM SPSS Statistics version 27 (14).

Results

Nutrient Contents: The results indicate that FP level has a significant effect on DM ($P<0.001$), CP ($P<0.001$), and NDF ($P<0.01$) (Table 2). The highest DM values were obtained from the 80% TRI + 20% FP and 60% TRI + 40% FP, which were similar to each other but higher than those from 40% TRI + 60% FP and 20% TRI + 80% FP. For CP, the highest values were recorded in 20% TRI +

80% FP and 40% TRI + 60% FP, whereas the lowest value occurred in 80% TRI + 20% FP. The NDF content was higher in the 80% TRI + 20% FP group than in the 20% TRI + 80% FP group. However, no significant differences among FP levels were found for CA or OM (P>0.05). The additive type exerted a significant influence on DM (P<0.05), CA (P<0.05), OM (P=0.05), NDF (P<0.001), and ADF (P<0.001), but not on CP (P>0.05). The supplementation of molasses resulted in higher DM and CA values in comparison with the control, but lower NDF and ADF values. The control group exhibited the highest OM content (93.49%), whereas the lowest was found in the molasses group. A considerable degree of interaction between FP level and additive was identified for NDF (P<0.05) and ADF (P<0.05). For NDF, in the 80% TRI + 20% FP group, the control exhibited a higher value than both inoculant and molasses. In the 40% TRI + 60% FP group, the control and inoculant values were higher than the molasses value. In the case of ADF, the control group exhibited a higher value than the inoculant and molasses groups. In a similar manner, within the 40% TRI + 60% FP group, the control and inoculant levels were higher than the molasses level.

Fermentation Parameters: The FP level has a significant effect on the LA content and ammonia-N concentration (P<0.001) (Table 3). The highest LA values were observed in the 20% TRI + 80% FP group (2.75%), followed by the 40% TRI + 60% FP group (2.29%) and the 60% TRI + 40% FP group (1.97%), with the lowest value in the 80% TRI + 20% FP group (1.47%). Ammonia-N levels were found to be significantly lower in the 80% TRI + 20% FP group (0.76%) in comparison to the other FP levels, which exhibited similar values ranging from 0.93 to 1.05%. No significant interactions between FP and additive were detected for pH, AA, PA, or BA (P>0.05). Likewise, the interaction was not significant for LA and ammonia-N, indicating that these parameters were not affected by the combined treatments. In this FP level, molasses supplementation resulted in a higher LA value (2.77%) than the control (1.83%), with inoculant (2.28%) showing an intermediate value that was not significantly different from either group. In a similar manner, the ammonia-N content in the 40% TRI + 60% FP group was highest in the molasses group (1.21%) and lowest in the inoculant group (0.89%), with the control group (1.05%) intermediate between them.

Table 2. Nutritional values of the silage materials examined in the study (DM%).

	DM	CA	OM	CP	NDF	ADF
FP Level						
80% TRI+20% FP	42.26±0.89^{a}	6.59±0.29	93.41±0.29	10.14±0.25^{b}	42.89±1.54^{a}	25.60±1.08
60% TRI+40% FP	42.31±0.74^{a}	7.58±0.44	92.42±0.44	11.01±0.31^{b}	41.07±1.06^{ab}	25.50±0.66
40% TRI+60% FP	33.94±0.60^{b}	7.38±0.41	92.62±0.41	12.26±0.27^{a}	39.08±1.30^{b}	24.07±0.85
20% TRI+80% FP	33.32±1.16^{b}	7.28±0.56	92.72±0.56	12.68±0.30^{a}	37.63±1.22^{b}	23.57±0.68
P	<0.001	0.36	0.36	<0.001	0.004	0.07
Additive						
Control	36.46±1.38^{b}	6.51±0.21^{b}	93.49±0.21^{a}	11.28±0.43	42.93±1.07^{a}	26.89±0.62^{a}
Inoculant	37.68±1.54^{ab}	7.12±0.36^{ab}	92.88±0.36^{ab}	11.59±0.36	41.06±1.08^{a}	24.88±0.63^{b}
Molasses	39.74±0.88^{a}	7.99±0.44^{a}	92.01±0.44^{b}	11.70±0.25	36.51±0.84^{b}	22.28±0.44^{c}
P	0.004	0.02	0.02	0.41	<0.001	<0.001
FP Level x Additive	0.21	0.54	0.54	0.09	0.18	0.62
80% TRI+20% FP						
Control	40.94±2.60	6.04±0.22	93.96±0.22	9.53±0.34	47.64±2.29^{a}	28.97±1.89^{a}
Inoculant	42.93±0.35	6.94±0.39	93.06±0.39	10.20±0.57	42.57±0.63^{b}	25.27±0.83^{b}
Molasses	42.93±0.98	6.78±0.78	93.22±0.78	10.68±0.20	38.44±2.53^{b}	22.54±1.30^{b}
P	0.48	0.64	0.64	0.22	0.002	<0.001
60% TRI+40% FP						
Control	40.67±1.82	6.02±0.30^{b}	93.98±0.30^{a}	10.17±0.54	43.02±1.52	27.07±0.82^{a}
Inoculant	43.57±0.32	7.73±0.37^{ab}	92.27±0.37^{ab}	11.51±0.51	42.20±1.76	26.11±0.82^{a}
Molasses	42.69±1.04	8.98±0.67^{a}	91.02±0.67^{b}	11.35±0.35	38.01±1.44	23.33±0.93^{b}
P	0.30	0.02	0.02	0.09	0.10	0.06
40% TRI+60% FP						
Control	33.29±0.93	6.82±0.42	93.18±0.42	12.41±0.46	40.06±1.71^{a}	25.60±1.08^{a}
Inoculant	32.37±0.54	7.26±0.90	92.74±0.90	11.66±0.59	43.03±1.22^{a}	25.22±1.69^{a}
Molasses	36.17±0.44	8.05±0.76	91.95±0.76	12.71±0.17	34.15±0.85^{b}	21.37±0.46^{b}
P	0.12	0.47	0.47	0.27	0.03	0.02
20% TRI+80% FP						
Control	30.95±1.12^{b}	7.16±0.50	92.84±0.50	13.00±0.48	41.02±1.05	25.91±0.12^{a}
Inoculant	31.85±2.33^{b}	6.54±1.12	93.46±1.12	12.98±0.56	36.46±2.94	22.92±1.32^{ab}
Molasses	37.17±0.74^{a}	8.15±1.22	91.85±1.22	12.05±0.51	35.42±0.91	21.88±0.60^{b}
P	0.004	0.28	0.28	0.27	0.06	0.04

DM: Dry matter, CA: Crude ash, OM: Organic matter, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber. FP: Forage pea, TRI: Triticale. ^{a,b}:Values within a column with different superscripts differ significantly at P<0.05.

Table 3. Fermentation parameters of silage materials examined in the study (DM%).

	pH	LA	AA	PA	BA	Ammonia-N
FP Level						
80% TRI+20% FP	4.21±0.03	1.47±0.11^{c}	0.21±0.01	0.00±0.00	0.00±0.00	0.76±0.02^{b}
60% TRI+40% FP	4.25±0.06	1.97±0.13^{b}	0.25±0.02	0.00±0.00	0.00±0.00	0.93±0.03^{a}
40% TRI+60% FP	4.15±0.05	2.29±0.14^{b}	0.25±0.02	0.01±0.00	0.02±0.01	1.05±0.06^{a}
20% TRI+80% FP	4.15±0.07	2.75±0.11^{a}	0.23±0.02	0.00±0.00	0.00±0.00	0.97±0.05^{a}
P	0.50	<0.001	0.51	0.31	0.11	<0.001
Additive						
Control	4.18±0.05	2.10±0.18	0.21±0.01	0.00±0.00	0.01±0.01	0.90±0.04
Inoculant	4.15±0.02	2.07±0.13	0.24±0.02	0.01±0.00	0.01±0.00	0.90±0.04
Molasses	4.24±0.06	2.19±0.17	0.25±0.01	0.00±0.00	0.00±0.00	0.98±0.05
P	0.41	0.67	0.18	0.24	0.47	0.21
FP Level x Additive	0.40	0.06	0.79	0.75	0.83	0.08
80% TRI+20% FP						
Control	4.25±0.06	1.53±0.22	0.18±0.03	0.00±0.00	0.00±0.00	0.78±0.02
Inoculant	4.18±0.06	1.47±0.17	0.20±0.02	0.00±0.00	0.00±0.00	0.75±0.03
Molasses	4.19±0.06	1.42±0.24	0.23±0.02	0.00±0.00	0.00±0.00	0.75±0.03
P	0.85	0.92	0.57	0.98	1.00	0.91
60% TRI+40% FP						
Control	4.21±0.14	2.02±0.26	0.20±0.03	0.00±0.00	0.01±0.00	0.91±0.07
Inoculant	4.20±0.05	2.01±0.27	0.27±0.02	0.01±0.00	0.00±0.00	0.92±0.02
Molasses	4.35±0.09	1.89±0.23	0.26±0.05	0.00±0.00	0.00±0.00	0.97±0.08
P	0.48	0.88	0.35	0.94	0.92	0.85
40% TRI+60% FP						
Control	4.23±0.09	1.83±0.08^{b}	0.20±0.03	0.01±0.00	0.04±0.03	1.05±0.10^{ab}
Inoculant	4.13±0.03	2.28±0.10^{ab}	0.28±0.06	0.01±0.01	0.02±0.02	0.89±0.06^{b}
Molasses	4.08±0.12	2.77±0.20^{a}	0.25±0.03	0.00±0.00	0.01±0.00	1.21±0.12^{a}
P	0.54	<0.01	0.33	0.07	0.15	<0.01
20% TRI+80% FP						
Control	4.06±0.07	3.02±0.28	0.24±0.01	0.00±0.00	0.00±0.00	0.85±0.03
Inoculant	4.08±0.01	2.52±0.12	0.21±0.07	0.01±0.00	0.01±0.00	1.05±0.12
Molasses	4.33±0.19	2.69±0.06	0.26±0.01	0.00±0.00	0.00±0.00	0.99±0.03
P	0.09	0.22	0.59	0.83	0.92	0.13

LA: Lactic acid. AA: Acetic acid. PA: Propionic acid. BA: Butyric acid. FP: Forage pea, TRI: Triticale. $^{a.b.c}$ Values within a column with different superscripts differ significantly at P<0.05.

Digestibility and Energy Values: The FP level exerts a significant influence on IVDMD (P<0.01), ME (P<0.05), and NEL (P<0.01) (Table 4). The highest values for all three parameters were observed in the 20% TRI + 80% FP group. This was statistically similar to the 40% TRI + 60% FP group, but higher than the 60% TRI + 40% FP and 80% TRI + 20% FP groups. The lowest values were generally recorded in the 80% TRI + 20% FP group. The effects of the additive type on all parameters were found to be highly significant (P<0.001). Molasses supplementation yielded the highest IVDMD, ME, and NEL values, which differed significantly from both the control and inoculant groups, which did not differ from each other. The lowest values were recorded in the inoculant group. A substantial FP × additive interaction was identified for IVDMD (P<0.05), ME (P<0.05), and NEL (P<0.05). In the 40% TRI + 60% FP group, molasses supplementation resulted in the highest IVDMD, ME, and NEL values, while the inoculant group had the lowest with the control group at intermediate levels. A similar pattern was observed in the 20% TRI + 80% FP group, where molasses supplementation produced the highest values and control

the lowest, with inoculant values being intermediate. No significant within-level differences were observed for the 60% TRI + 40% FP or 80% TRI + 20% FP groups.

Physical Analysis: According to results, FP level significantly affected the FLIEG value (P<0.001). The 80% TRI + 20% FP and 60% TRI + 40% FP groups had significantly higher FLIEG values than the 40% TRI + 60% FP and 20% TRI + 80% FP groups, which were similar to each other (Table 5). Additive type did not significantly influence any of the measured parameters, including the FLIEG value (P>0.05). No significant FP × additive interactions were observed for any of the physical or sensory traits (P>0.05), indicating that the effect of FP level on these parameters was consistent across additive treatments.

Table 4. Digestibility and energy values of the studied silage materials

	IVDMD	ME	NEL
FP Level			
80% TRI+20% FP	61.20±0.89^{b}	2.70±0.04^{b}	1.38±0.02^{b}
60% TRI+40% FP	62.14±1.22^{b}	2.74±0.05^{b}	1.40±0.03^{b}
40% TRI+60% FP	64.17±1.24^{ab}	2.83±0.05^{ab}	1.45±0.03^{ab}
20% TRI+80% FP	65.99±1.49^{a}	2.91±0.07^{a}	1.50±0.04^{a}
P	<0.01	0.003	0.004
Additive			
Control	62.29±0.90^{b}	2.75±0.04^{b}	1.41±0.02^{b}
Inoculant	61.25±0.95^{b}	2.70±0.04^{b}	1.38±0.02^{b}
Molasses	66.59±1.10^{a}	2.93±0.05^{a}	1.51±0.03^{a}
P	<0.001	<0.001	<0.001
FP Level x Additive	0.02	0.02	0.03
80% TRI+20% FP			
Control	61.85±2.17	2.73±0.10	1.40±0.05
Inoculant	58.73±0.70	2.59±0.03	1.32±0.02
Molasses	63.01±0.54	2.77±0.03	1.42±0.02
P	0.16	0.19	0.19
60% TRI+40% FP			
Control	60.09±1.62	2.65±0.07	1.35±0.04
Inoculant	61.66±2.23	2.72±0.10	1.39±0.05
Molasses	64.68±2.26	2.85±0.10	1.40±0.03
P	0.13	0.14	0.14
40% TRI+60% FP			
Control	65.70±0.31^{b}	2.90±0.01^{a}	1.48±0.01^{a}
Inoculant	58.92±0.96^{b}	2.60±0.04^{b}	1.32±0.02^{b}
Molasses	67.88±1.21^{a}	2.99±0.05^{a}	1.54±0.03^{a}
P	<0.001	<0.001	<0.001
20% TRI+80% FP			
Control	61.51±1.79^{b}	2.71±0.08^{b}	1.39±0.04^{b}
Inoculant	65.67±1.16^{b}	2.90±0.05^{b}	1.49±0.03^{b}
Molasses	70.79±2.34^{a}	3.12±0.10^{a}	1.61±0.06^{a}
P	<0.001	<0.001	<0.001

*IVDMD: In vitro dry matter digestibility, ME: Metabolizable energy (Mcal/kg), NEL: Lactation net energy values (Mcal/kg). FP: Forage pea, TRI: Triticale. $^{a.b.c}$ Values within a column with different superscripts differ significantly at P<0.05.

Table 5. Physical evaluations of the studied silage materials.

	Odor	Appearance	Color	Physical condition	FLIEG
FP Level					
80% TRI+20% FP	12.17±0.90	3.75±0.25	1.92±0.83	17.83±1.03	124.47±4.02[a]
60% TRI+40% FP	12.00±1.13	4.00±0.00	1.75±0.13	17.75±1.23	119.59±2.92[a]
40% TRI+60% FP	12.83±1.00	4.00±0.00	1.83±0.11	18.67±1.00	105.35±3.58[b]
20% TRI+80% FP	13.25±0.41	3.42±0.31	1.83±0.11	18.50±0.69	105.52±3.21[b]
P	0.75	0.19	0.80	0.90	<0.001
Additive					
Control	12.50±0.81	3.69±0.22	1.81±0.10	18.00±0.88	110.91±3.25
Inoculant	12.20±0.86	3.81±0.19	1.81±0.10	17.81±0.95	114.51±3.81
Molasses	13.00±0.66	3.88±0.13	1.87±0.09	18.75±0.73	115.78±3.84
P	0.77	0.77	0.88	0.74	0.52
FP Level x Additive	0.37	0.86	0.83	0.54	0.64
80% TRI+20% FP					
Control	12.00±1.16	3.25±0.75	1.75±0.25	17.00±1.91	118.40±6.59
Inoculant	10.50±2.36	4.00±0.00	2.00±0.00	16.50±2.36	128.86±3.32
Molasses	14.00±0.00	4.00±0.00	2.00±0.00	20.00±0.00	126.15±10.16
P	0.30	0.26	0.61	0.34	0.47
60% TRI+40% FP					
Control	14.00±0.00	4.00±0.00	1.75±0.25	19.75±0.25	118.05±7.33
Inoculant	11.50±2.50	4.00±0.00	1.75±0.25	17.25±2.75	124.14±1.87
Molasses	10.50±2.36	4.00±0.00	1.75±0.25	16.25±2.59	116.57±5.08
P	0.28	1.00	1.00	0.37	0.66
40% TRI+60% FP					
Control	11.00±3.00	4.00±0.00	2.00±0.00	17.00±3.00	102.47±4.45
Inoculant	13.50±0.50	4.00±0.00	1.75±0.25	19.25±0.75	99.44±7.11
Molasses	14.00±0.00	4.00±0.00	1.75±0.25	19.75±0.25	114.14±5.52
P	0.36	1.00	0.61	0.52	0.22
20% TRI+80% FP					
Control	13.00±1.00	3.50±0.50	1.75±0.25	18.25±1.03	104.71±4.75
Inoculant	13.25±0.75	3.25±0.75	1.75±0.25	18.25±1.75	105.60±4.78
Molasses	13.50±0.50	3.50±0.50	2.00±0.00	19.00±1.00	106.24±8.22
P	0.98	0.86	0.61	0.94	0.98

FP: Forage pea, TRI: Triticale. [a.b.c] Values within a column with different superscripts differ significantly at P<0.05.

Discussion and Conclusion

The results indicated that increasing the proportion of forage peas enhanced LA content and digestibility. However, excessively high inclusion levels of forage peas (e.g., 80%) could adversely affect fermentation quality. Triticale also played a crucial role in improving fermentation efficiency, as its high fermentability provides readily available energy that supports microbial activity and silage stability. Previous studies (5, 17) have similarly reported that ensiling triticale with legumes helps achieve a better balance between fermentable carbohydrates and proteins, thereby optimizing the overall fermentation process.

Increasing pea ratios resulted in significant increases in CP content, particularly in the 80% pea-supplemented group, which had the highest CP values, confirming the protein-rich nature of peas (11, 44). This finding is also consistent with the higher crude protein content of forage pea compared to triticale observed in the fresh forages before ensiling. Peas are a valuable source of protein for ruminants, and similar findings were observed in this study. However, triticale contributed to improved silage energy values, providing a starch-rich substrate for fermentation (15). Compared to other cereals such as rye or wheat, triticale has been reported to enhance LAB growth, stabilizing fermentation and improving DM

recovery (10). Consistently, Jung et al. (17) reported that fermentation with LAB and carbohydrate-rich forages, such as triticale, enhanced digestibility and energy values. In terms of additives, molasses supplementation significantly reduced NDF, ADF, and OM contents, which can be attributed to its high concentration of readily fermentable carbohydrates. The easily available sugars in molasses provide an immediate substrate for LAB, thereby accelerating fermentation and leading to a rapid decline in pH. The marked reduction (~9 units) in NDF content following molasses supplementation may also result from enhanced microbial fermentation supported by these readily available sugars, which promote LA production and acidification, facilitating partial solubilization of hemicellulosic cell wall components and thereby lowering fiber fractions (37, 38). However, the relatively low NFC concentration in triticale, possibly due to its harvest at the boot stage, may have limited carbohydrate availability compared with forage pea, which naturally contains higher soluble sugar levels (35). Consequently, the fermentation dynamics were influenced not only by the additives but also by the compositional differences between forage pea and triticale. Furthermore, the utilization of soluble carbohydrates during fermentation contributed to the reduction in OM content. Collectively, these effects indicate enhanced fiber degradation and improved overall silage digestibility (15, 24, 45).

When fermentation parameters were studied, it was observed that LA production increased with an increasing FP ratio, which improved the fermentation quality of silage. This effect can be explained by the higher levels of non-fiber carbohydrates (NFC) and soluble sugars typically present in forage pea herbage compared to triticale. The abundance of rapidly fermentable substrates provides an immediate energy source for LAB, thereby enhancing their activity, promoting faster acidification, and resulting in greater LA accumulation. In addition, the relatively higher crude protein content of forage pea herbage may further stimulate microbial growth during ensiling. Together, these compositional advantages of forage pea over triticale account for the observed increase in LA concentration and the improved fermentation quality. This finding was similar to the study by Muck et al. (26), indicating that additives accelerate the fermentation process and promote LA production. Increased LA production rapidly lowers the pH of silage, suppresses the growth of undesirable microorganisms, and increases fermentation stability (2, 18, 19, 24, 47). However, it was observed that the addition of 60% and 80% FP had negative effects on some fermentation parameters. This is consistent with the literature showing that legume-rich mixtures with lower DM and higher buffering capacity can negatively affect fermentation quality by delaying pH decline and promoting proteolysis, thereby increasing NH_3–N production during fermentation (46). Although triticale's starch content is known to facilitate rapid pH decline and enhance lactic fermentation, in the present study FP inclusion also contributed to increased LA, suggesting that multiple substrate characteristics, including soluble carbohydrates and buffering capacity, collectively influenced the fermentation profile (32, 45). In this study, higher TRI inclusion was associated with lower Ammonia-N levels, suggesting reduced proteolysis, which is consistent with previous findings (16, 20, 31, 45). Although the higher crude protein content observed in forage pea–inclusive silages suggests improved nutritional potential, this increase mainly reflects the intrinsic composition of forage pea rather than true preservation of protein during ensiling. Because FP inherently contains higher crude protein than triticale, the observed CP differences among silages primarily reflect the initial composition of the forages. Therefore, accurate interpretations of protein retention should rely on within-treatment comparisons (i.e., additive effects) rather than between mixtures differing in initial CP contents.

In terms of digestibility, a significant increase in digestibility and energy values was observed with increasing levels of FP. In particular, the 80% FP supplemented group was found to have the highest IVDMD and ME values. These results support the high digestibility potential of legumes and their important role in ruminant diets (1, 24). Wang et al. (43) also observed that fermentation with LAB, increased digestibility and energy values. In this context, the increase in digestibility by molasses supplementation in our study is consistent with the findings in the literature (27, 30, 37).

Evaluating the effects of molasses and inoculants on silage fermentation, it was observed that molasses gave more positive results than inoculants, particularly in terms of LA production and ammonia-N levels in certain treatment groups. Molasses, as a sugar source in the fermentation process, enhances LA production and consequently increases energy values (16, 32, 38).

In the present study, molasses supplementation in certain FP ratios appeared to enhance LA production and influence ammonia-N levels, reflecting a beneficial role in fermentation quality. This effect is likely attributable to the additional fermentable carbohydrates supplied by molasses, which stimulated LAB activity, accelerated pH decline, and stabilized the silage. However, while molasses supplementation tended to enhance LA concentration and reduce fiber fractions overall, statistically significant improvements were observed only in the 40% TRI + 60% FP group. Therefore, the influence

of molasses was treatment-specific rather than universal across all mixture ratios. The lower ammonia-N values suggest reduced proteolysis during ensiling, although firm conclusions on true protein preservation require consideration of the initial crude protein composition of the fresh forages. Similar findings have been reported by Copani et al. (11), who observed that silages made from protein-rich forages exhibited improved digestibility and nutritional value. Likewise, other studies have highlighted that carbohydrate supplementation, particularly in legume silages, supports LA fermentation and reduces nitrogen losses (26, 44), reinforcing the positive effects of pea–molasses combinations observed in this study. The sensory and physical quality parameters of silage, including odor, appearance, color, physical condition, and FLIEG score, were largely unaffected by additive type. However, forage composition had a notable influence on the FLIEG score, an important indicator of silage quality. Higher triticale inclusion tended to improve this score, suggesting enhanced fermentation efficiency, while greater proportions of field pea appeared to slightly reduce it. This reduction may be linked to the higher buffering capacity of protein-rich forages, which can slow the pH decline during ensiling and alter fermentation dynamics. These findings align with previous studies indicating that energy-rich cereals, such as triticale, can support rapid LA production and reduce spoilage risk (15). Although the effect of additives on FLIEG score was not statistically significant, molasses supplementation showed a slight tendency to improve scores compared with other treatments. This effect is likely due to the additional fermentable carbohydrates provided by molasses, which stimulate LA bacteria activity and promote better fermentation stability (20, 32). Similarly, LAB-based inoculants have been reported to enhance LA fermentation and improve aerobic stability in silages (5).

In conclusion, the results highlight the importance of carefully adjusting the pea ratio in silage mixtures and suggest that future studies could further contribute to developing more balanced and high-quality silages by investigating the combined effects of different forage crops and additives.

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Ethical Statement

This study does not present any ethical concerns.

Conflict of Interest

The authors declared that there is no conflict of interest.

Author Contributions

ŞE conceived and designed the study, coordinated the research activities, performed data collection and analysis, and prepared the initial draft of the manuscript. MAK contributed to the development of the experimental design, validated the analytical procedures, and critically revised the manuscript. GŞ was responsible for statistical analysis, data visualization, and assisted in manuscript editing. TE supported the experimental setup, resource management, and project administration. KK contributed to the fieldwork, sample collection, and provided technical assistance throughout the study. All authors have read and approved the final version of the manuscript.

Data Availability Statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

References

1. **Addah W, Baah J, Okine EK, et al** (2012): *Use of thermal imaging and the in-situ technique to assess the impact of an inoculant with feruloyl esterase activity on the aerobic stability and digestibility of barley silage*. Can J Anim Sci, **92**, 381-394.
2. **Adesokan IA, Odetoyinbo BB, Okanlawon BM** (2009): *Optimization of lactic acid production by lactic acid bacteria isolated from some traditional fermented food in Nigeria*. Pak J Nutr, **8**, 611-615.
3. **AOAC** (2005): *Official Methods of Analysis. 18th ed. Association of Official Analytical Chemists, Maryland, USA.*
4. **Barnett AJ** (1951): *The colorimetric determination of lactic acid in silage*. Biochem J, **49**, 527-529.
5. **Baron VS, Juskiw PE, Aljarrah M** (2015): Triticale as a Forage. In *Triticale* (pp. 189-212). Cham: Springer International Publishing.
6. **Borreani G, Cavallarin L, Antoniazzi S, et al** (2006): *Effect of the stage of growth, wilting and inoculation in field pea (Pisum sativum L.) silages. I. Herbage composition and silage fermentation.* J Sci Food Agric, **86**, 1377-1382.
7. **Borreani G, Tabacco E, Schmidt RJ, et al** (2018): *Silage review: Factors affecting dry matter and quality losses in silages.* J Dairy Sci, **101,** 3952–3979.
8. **Can M, Kaymak G, Gülümser E, et al** (2019): *Orman üçgülü yulaf karışımlarının silaj kalitesinin belirlenmesi*. OMUANAJAS, **34**, 371-376.

9. **Canbolat Ö, Akbay KC, Kamalak A** (2019): *Yem bezelyesi silajlarında karbonhidrat kaynağı olarak melas kullanılma olanakları*. KSU Tar Doga Derg, **22**, 122-130.
10. **Chen L, Bai S, You M, et al** (2020): *Effect of a low temperature tolerant lactic acid bacteria inoculant on the fermentation quality and bacterial community of oat round bale silage.* Anim Feed Sci Technol, **269**, 114669.
11. **Copani G, Niderkorn V, Anglard F, et al** (2016): *Silages containing bioactive forage legumes: a promising protein-rich feed source for growing lambs*. Grass and Forage Sci, **71**, 622-631.
12. **Fraser MD, Fychan R, Jones R** (2001): *The effect of harvest date and inoculation on the yield, fermentation characteristics and feeding value of forage pea and field bean silages.* Grass Forage Sci, **56**, 218-230.
13. **Goering HK, Van Soest PJ** (1970): *Forage Fibre Analyses. Apparatus, Reagent, Procedures and Applications*, USDA Agricultural Handbook No: 379.
14. **IBM Corp** (2020): IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp, 2020.
15. **Jacobs JL, Ward GN** (2013): *Effect of cereal and pea monocultures and combinations and silage additives on whole-crop cereal silage nutritive and fermentation characteristics.* Animal Prod Sci, **53**, 427-436.
16. **Jones BA, Satter LD, Muck RE** (1992): *Influence of bacterial inoculant and substrate addition to lucerne ensiled at different dry matter contents.* Grass Forage Sci, **47**, 19-27.
17. **Jung JS, Ravindran B, Soundharrajan I, et al** (2022): *Improved performance and microbial community dynamics in aerobic fermentation of triticale silages at different stages.* Bioresource Tech, **345**, 126485.
18. **Kallida R, Benbrahim N, Gaboun F, et al** (2022): *Forage yield and quality of vetch-triticale and pea-triticale mixtures under Moroccan conditions.* Acta Fytotechn Zootechn, **25**, 294-302.
19. **Kim DH, Lee KD, Choi** KC (2021): *Role of LAB in silage fermentation: Effect on nutritional quality and organic acid production-An overview.* AIMS Agriculture & Food, **1216,** 216-234.
20. **Koc F, Levent Ozduven M, Coskuntuna L, et** al (2009): *The effects of inoculant lactic acid bacteria on the fermentation and aerobic stability of sunflower silage.* Poljoprivreda, **15**, 47-52.
21. **Kung Jr L, Shaver RD, Grant RJ, et al** (2018): *Silage review: Interpretation of chemical, microbial, and organoleptic components of silages.* J Dairy Sci, **101**, 4020-4033.
22. **Marten GC, Barnes RF** (1979): Prediction of Energy Digestibility of Forages with in Vitro Rumen Fermentation and Fungal Enzyme Systems. In: WJ Pigden, CC Balch, and M Graham (Eds): Proc. Int. Workshop on Standardization of Analytical Methodology for Feeds, International Development Research Center, Ottawa, Canada.
23. **McDonald P, Henderson AR, Heron SJE** (1991): The Biochemistry of Silage. Chalcombe Publications, Chalcombe, Marlow, UK.
24. **Miller MD, Kokko C, Ballard CS, et al** (2021): *Influence of fiber degradability of corn silage in diets with lower and higher fiber content on lactational performance, nutrient digestibility, and ruminal characteristics in lactating Holstein cows.* J Dairy Sci, **104**, 1728-1743.
25. **Mirza A, Çopur Doğrusöz M** (2024): *Silage yield and quality of forage peas and Hungarian vetch and triticale binary mixtures*. SJAFS, **38**, 434–444.
26. **Muck RE** (2013): *Recent advances in silage microbiology*. Agr Food Sci, **22**, 3-15.
27. **Muck RE, Nadeau EMG, McAllister TA, et al** (2018): *Silage review: Recent advances and future uses of silage additives*. J Dairy Sci, **101**, 3980-4000.
28. **Murray MH, Kephart KD, Eckert JW** (1990): Spring-Planted Pea and Triticale Production in Northern Idaho. Idaho Agricultural Experiment Station Bulletin No. 713. University of Idaho, College of Agriculture.
29. **Mustafa AF, Seguin P, Ouellet DR, et al** (2002): *Effects of cultivars on ensiling characteristics, chemical composition, and ruminal degradability of pea silage.* J Dairy Sci, **85**, 3411-3419.
30. **Öten M, Köse M** (2024): *Determination of the effects on silage quality of different additives added to vetch-triticale silage mixture*. TURKJRFS, **5**, 1-11.
31. **Pursiainen P, Tuori M** (2008): *Effect of ensiling field bean, field pea and common vetch in different proportions with whole-crop wheat using formic acid or an inoculant on fermentation characteristics*. Grass Forage Sci, **63**, 60-78.
32. **Ran Q, Guan H, Li H, et al** (2022): *Effect of formic acid and inoculants on microbial community and fermentation profile of wilted or un-wilted Italian ryegrass silages during ensiling and aerobic exposure*. Fermentation, **8**, 755.
33. **Republic of Türkiye Ministry of Agriculture and Forestry** (2023): Available at: https://www.tarimorman.gov.tr/Sayfalar/EN/AnaSayfa.aspx (Accessed: January 18, 2023).
34. **Rondahl T, Bertilsson J, Martinsson K** (2011): *Effects of maturity stage, wilting and acid treatment on crude protein fractions and chemical composition of whole crop pea silages (Pisum sativum L.).* Anim Feed Sci Tech, **163**, 11-19.
35. **Schultz ME** (2023): *Effects of maturity at harvest of triticale and dietary forage inclusion on production performance, nutrient utilization, and milk fatty acid profile of lactating dairy cows* Master's thesis. Virginia Polytechnic Institute and State University, USA.
36. **Seydoşoğlu S** (2019): *Farklı oranlarda karıştırılan yem bezelyesi (Pisum sativum L.) ve arpa (Hordeum vulgare L.) hâsıllarının silaj ve yem kalitesine etkisi*. J Agric Fac Ege Univ, **56**, 297-302.
37. **Şen G, Erol T, Kara K, et al** (2022): *The effect of microbial inoculants and molasses on quality and in vitro digestibility of silages prepared with different proportions of ryegrass and Hungarian vetch.* Turk J Vet Anim Sci, **46**, 629-637.
38. **Tekin M, Kara K** (2020): *The forage quality and the in vitro ruminal digestibility, gas production, organic acids, and some estimated digestion parameters of tomato herbage silage with molasses and barley.* Turk J Vet Anim Sci, **44**, 201-213.
39. **Tilley JM, Terry RA** (1963): *A two-stage technique for in vitro digestion of forage.* Grass Forage Sci, **18**, 104-111.
40. **Turkish Statistical Institute** (2022): Available at: https://data.tuik.gov.tr/Bulten/Index?p=Hayvansal-

%C3%9Cretim-%C4%B0statistikleri-Haziran-2022-45594&dil=1 (Accessed January 18, 2023).

41. **Udén P, Robinson PH, Wiseman J** (2005): Use of detergent system terminology and criteria for submission of manuscripts on new, or revised, analytical methods as well as descriptive information on feed analysis and/or variability. Anim Feed Sci Technol, **118**, 181-186.
42. **Van Soest PJ, Robertson JB** (1979): Systems of Analyses for Evaluation of Fibrous Feed. In: WJ Pigden, CC Balch, and M Graham (Eds): Proc. Int. Workshop on Standardization of Analytical Methodology for Feeds, International Development Research Center, Ottawa, Canada.
43. **Wang Z, Huang J, Ma S, et al** (2021): *Novel heating technologies to improve fermentation efficiency and quality in wheat products: A short review.* Grain & Oil Sci Tech, **4**, 81-87.
44. **Weinberg ZG, Ashbell G, Azrieli A, et al** (1993): *Ensiling peas, ryegrass and wheat with additives of lactic acid bacteria (LAB) and cell wall degrading enzymes.* Grass Forage Sci, **48**, 70-78.
45. **Weiss WP, Conrad HR, St Pierre NR** (1992): *A theoretically based model for predicting total digestible nutrient values of forages and concentrates.* Anim Feed Sci Tech, **39**, 95-110.
46. **Xue Z, Wang Y, Yang H, et al** (2020): *Silage fermentation and in vitro degradation characteristics of orchardgrass and alfalfa intercrop mixtures as influenced by forage ratios and nitrogen fertilizing levels.* Sustainability, **12**, 871.
47. **Yan Y, Li X, Guan H, et al** (2019): *Microbial community and fermentation characteristics of Italian ryegrass silage prepared with corn stover and lactic acid bacteria.* Bioresour Technol, **279**, 166-173.