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Research Article

The Effects of Various Supplements on In Situ Dry Matter Degradability Characteristics of Maize Silage*

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Abstract: The purpose of this study was to evaluate the effects of various supplements on the in situ dry matter degradability (DMD) characteristics of maize silages. The proportion of the supplements was 1% urea, 2% molasses and 5% cracked barley. In all silages 2% salt was used as the protector. Moreover, one of the silage groups was prepared without salt to examine its impact on DMD. The ingredients of the silages prepared in this study were 1) maize silage (S1), 2) maize silage + salt (S2), 3) maize silage + cracked barley + salt (S3), 4) maize silage + urea + cracked barley + salt (S4), 5) maize silage + urea + cracked barley + molasses + salt (S5), 6) maize silage + urea + salt (S6), 7) maize silage + molasses + salt (S7), 8) maize silage + molasses + cracked barley + salt (S8) and 9) maize silage + urea + molasses + salt (S9). The samples of the silages were incubated for 4, 8, 16, 24, 48, 72 and 96 h in rumen. In order to do this, 3 mature Akkaraman rams, of 70 kg live body weight, with ruminal cannulas were used in this experiment. The results of ANOVA indicated that the interaction between silages and incubation periods was not statistically significant ($P > 0.05$). However, there was evidence of a statistically significant difference in DMD between at least 2 silages, and incubation periods ($P < 0.01$). Regarding the degradability characteristics of a, a + b, Pe (2%), Pe (5%) and Pe (8%), there was also a statistically significant difference between at least 2 silages ($P < 0.01$). From the findings, an important conclusion is that the addition of various supplements to silage should positively influence DMD. The use of salt as a protector did not, however, have any significant effect on DMD. Furthermore, the results showed that molasses supplementation did not have any positive impact, as the other supplements had.

Key Words: Degradability, in situ, dry matter, maize silage, urea, molasses, barley

Mısır Silajına Bazı Katkı Maddeleri İlavelerinin in situ Kuru Madde Parçalanma Özelliklerine Etkileri

Özet: Bu çalışma, silajlık mısıra bazı katkı maddeleri ilavelerinin in situ kuru madde (KM) parçalanma özelliklerine etkisini belirlemek üzere yürütülmüştür. Bu amaçla 70 kg canlı ağırlığında rumen kanülü takılmış 3 baş ergin Akkaraman ırkı koç kullanılmıştır. Mısır silajları 4, 8, 16, 24, 48, 72 ve 96 saatlerde rumende inkübasyona bırakılmışlardır. Katkı maddelerinin oranları % 1 üre, % 2 melas ve % 5 arpa kırması olacak şekilde düzenlenmiştir. Bütün uygulamalara koruyucu olarak % 2 tuz ilave edilmiştir. Ayrıca tuzun etkisini de görmek bakımından bir gruba tuz katılmamıştır. Silajlık mısır (S1), silajlık mısır + tuz (S2), silajlık mısır + arpa kırması + tuz (S3), silajlık mısır + üre + arpa kırması + tuz (S4), silajlık mısır + üre + arpa kırması + melas + tuz (S5), silajlık mısır + üre + tuz (S6), silajlık mısır + melas + tuz (S7), silajlık mısır + melas + arpa kırması + tuz (S8) ve silajlık mısır + üre + melas + tuz (S9) olmak üzere 9 farklı silaj yapılmıştır. KM parçalanabilirliği bakımından mısır silajları ve inkübasyon süreleri arasındaki interaksiyon önemli bulunmamakla birlikte ($P > 0,05$) en az iki mısır silajı ve inkübasyon süresi arasındaki farklılık önemli bulunmuştur ($P < 0,01$). Ayrıca a, a + b, Pe (% 2), Pe (% 5) ve Pe (% 8) özellikleri bakımından en az 2 mısır silajı arasındaki farklılığın da istatistik olarak önemli olduğu saptanmıştır ($P < 0,01$). Sonuç olarak, mısır silajına katkı maddesi ilavesi KM parçalanabilirliğini olumlu yönde etkilemiştir. Koruyucu olarak kullanılan tuzun ilave edilmesi veya edilmemesinin KM parçalanabilirliği bakımından önemli bir etkiye sahip olmadığı görülmüştür. Melasın katkı maddesi olarak silaja ilave edilmesi diğer katkı maddelerinin sağladığı olumlu etkiyi sağlayamamıştır.

Anahtar Sözcükler: Parçalanabilirlik, in situ, kuru madde, mısır silajı, üre, melas, arpa

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Introduction

Biological supplements are generally used in ensilaging. These additives include ground or cracked barley, wheat bran, salts, dried sugar beet sediment, molasses and urea. As a supplement 20–50 kg of molasses, 30-50 kg of cracked grain, 50-70 kg of dry sugar beet sediment and 10-30 kg of urea can be added to 1 t of material. Maize is the one of the most important cereals used in ensilaging over all the world (1).

Proper timing of the harvest is one of the most important factors influencing the quality of the maize silage produced. The stage of maturity has an important effect on the amount of nutrients, as well as on the moisture in the plant. Maize harvested at the milk dough stage has more dry matter content. If maize is harvested at the milk dough stage, an increase in the Fleig point and high quality silage can be obtained without adding any supplements (1-3). However, there are also various supplements used to increase the flavor and amount of nutrients in the silage (3).

In addition to the Fleig point, pH is another important criterion in determining silage quality. pH is generally low, approximately around, or even less than 3.5, due to the high fermentable carbohydrate contents of maize. It is, however, known that the pH values should be around 4.0-4.2 for good quality silage (3,4). In spite of the use of pH as the quality criterion, the Fleig point that is calculated by means of the pH value of the silage provides more information than the other physical techniques (5).

The addition of wheat (cracked), maize (grain) and molasses diminished crude protein (CP). However, they did not influence or increase the pH of the silage (6-9). The addition of 3% or 4% molasses can result in noticeable fermentation increases. It has also been stated that in vitro dry matter (DM) digestibility is not affected by the addition of urea and/or molasses to the diet (8-10). Increases in pH, CP and in vitro digestibility, by 9%-14%, were obtained by urea supplementation of maize silage (11). In addition, there was no significant difference in DMD among the silages with added molasses or urea. While an increase in DMD was achieved by the addition of 0.5% urea compared with the control group, the fermentation quality of silage was negatively affected (9). It is reported that a supplement of 2.5% urea to maize silage caused higher in situ DMD than in the control group (12).

In situ DM loss over 48 h for 4 different maize species varied from 54.9%-65.7%, but there was no evidence that the difference between at least 2 species was statistically significant. The findings attained also indicated 15.60%-40.50% of a value, 38.80%-60.50% of b value, 73.20%-85.50% of a + b value and 1.9%-2.4% of c value (13).

There are also results showing that with regard to in situ effective DM degradability of maize silage, a, b, a + b and c values were 54%, 26%, 56%, 82% and 2.7%, respectively. (14).

The observed rumen DMD (g/kg DM) values from the experiments in which 11 different maize species were examined for 12, 24 and 48 h were 363-492, 492-614 and 616-680, respectively. The degradability parameters of a, b, a + b and c were 242-415, 313-526, 728-816 and 0.024-0.053, respectively (15).

In another study, in which DMD of maize silage was observed for a longer period than that mentioned above, DMD levels in maize silage for 0, 4, 8, 16, 24, 48 and 72 h incubation periods were calculated as, 33%, 39%, 46%, 52%, 63%, 68% and 80%, respectively. (16).

The objective of this study is to determine the effects of various supplements, such as cracked barley, molasses and urea, on the nutritive value of maize silage by evaluating the DMD characteristics. It also aims to advise farmers on the best supplement or supplements to be used in maize silage, depending on the findings achieved.

Materials and Methods

In this research, maize that was harvested and chopped at the milk dough stage was used. Supplements of 1% urea, 2% molasses and 5% cracked barley were added to silages. Salt was used as the protector in all silages. Maize was also used without the addition of salt to inspect the effect of salt on the DMD.

The ingredients of the silages prepared in this research were;

- Maize (S1)
- Maize + salt (S2)
- Maize + cracked barley + salt (S3)
- Maize + urea + cracked barley + salt (S4)
- Maize + urea + cracked barley + molasses + salt (S5)

- Maize + urea + salt (S6)
- Maize + molasses + salt (S7)
- Maize + molasses + cracked barley + salt (S8)
- Maize + urea + molasses + salt (S9)

The chemical compositions of the maize silages and silage qualities are given in Table 1. The ingredients and chemical compositions of the experimental diet and dry grass are also presented in Tables 2 and 3, respectively. The Weende method was employed to determine the chemical composition of maize silages, total mixed ratio (TMR) and dry grass (17).

Three mature Akkaraman rams, of 70 kg live body weight, with ruminal cannulas were used in this experiment. The animals were fed 540 g TMR and 900 g dry grass twice in a day.

Chemical composition and silage quality of silages: The chopped maize was kept for some time at the laboratory, then supplements were added to it. After that, 3-l glass jars were filled with the chopped maize and sealed. The jars were placed upside down, and the holes in the lids were opened to remove water from the jars. After this process the jars were settled into their normal position. The holes were closed again after the gas

Table 1. Chemical composition and silage quality of maize silages.

Chemical composition	Maize silages								
	S1	S2	S3	S4	S5	S6	S7	S8	S9
In fresh stage, %									
Dry matter, %	19.88	19.71	22.76	24.68	23.78	20.26	20.84	23.46	20.41
Organic matter, %	18.49	16.36	19.45	21.21	20.54	17.6	17.53	20.34	17.58
Crude protein, %	1.81	1.79	2.09	5.17	3.78	3.6	1.14	2.22	4.84
Ether extract, %	0.25	0.38	0.17	0.29	0.17	0.24	0.2	0.21	0.24
Crude fiber, %	7.15	6.86	6.04	5	6.28	6.81	9.23	7	6.56
Crude ash, %	1.39	3.5	3.31	3.47	3.24	2.71	3.31	3.12	2.83
Nitrogen free extract,%	9.28	9.31	12.88	12.5	11.89	8.2	8.82	12.39	7.35
In dry matter, %									
Organic matter, %	93.01	83	85.46	85.96	86.36	86.62	84.13	86.69	86.13
Crude protein, %	9.11	9.06	9.17	20.95	15.92	17.78	5.46	9.48	23.71
Ether extract, %	1.26	1.9	0.74	1.17	0.72	1.16	0.94	0.91	1.16
Crude fiber, %	35.95	34.81	26.52	20.24	26.39	33.59	44.28	29.82	32.13
Crude ash, %	6.99	17	14.54	14.05	13.64	13.38	15.87	13.31	13.87
Nitrogen free extract,%	46.7	37.23	49.02	43.59	43.33	34.09	33.45	46.49	29.13
Silage quality									
PH	3.9	4.24	4.6	4.49	4.29	4.1	4.02	4.41	4.35
Flieg Point	88.76	74.82	66.52	74.76	80.96	81.52	85.88	75.52	71.82
Silage Quality Value	VG	G	G	G	VG	VG	VG	G	G

* VG: Very good, G: Good

Table 2. Chemical composition of total mixed ration and dry grass (%).

Feeds	DM	Ash	CP	Ether extract	Crude fiber	Nitrogen free extract
TMR	90.63	4.58	15.4	2.4	9.82	58.43
Dry Grass	89.00	6.50	7.23	1.70	32.15	41.42

Table 3. Composition of total mixed ratio.

Feeds	%
Barley	50
Sunflower seed meal	25
Wheat bran	23.8
Salt	0.5
CaCO3	0.5
Vitamin mix*	0.10
Mineral mix**	0.10
Total	100

* contains 18,000,000 IU Vitamin A, 3,000,000 IU Vitamin D_3, 30,000 mg Vitamin E, 5000 mg Vitamin B_1 per kilogram of premix.

** contains 50,000 mg Mn, 50,000 mg Fe, 50,000 mg Zn, 150 mg Co, 800 mg I, 150 mg Se per kilogram of premix.

release. After all these stages, they were left at the laboratory for fermentation for 45 days. At the end of this period, the jars were opened and their pH values were measured. The Flieg points were calculated by means of the pH values and DM of the silages by using the equation given below.

Flieg Point = 220 + (2*DM-15) – 40*pH

Determination of in situ DMD characteristics of maize silages: DMD and washing losses of silage samples were determined by the nylon bag technique (18). Each silage sample was incubated in rumen for 4, 8, 16, 24, 48, 72 and 96 h. Rumen degradability characteristics were calculated by means of the equation $P = a + b\ (1\text{-}e^{-ct})$ (19) where, p: DMD in t incubation period, a: amount of easily degradable DM, b: amount of insoluble but degradable DM in time, c: velocity constant of DM degradability, a + b: maximum DMD and t: incubation period (hour).

The effective DMD values of the silage samples were computed using the equation $Pe = a + bc/(c + k)\ e^{-(c+k)\ t}$ (19) where, Pe: effective DMD, k: velocity of DM passing through the rumen (k value is 8% for high producing dairy cows, 5% for beef cows, sheep, goats and low producing dairy cows, and 2% for weaning cows) (18). The meanings of a, b, a + b and c are the same as explained above. The rumen degradability characteristics of silage samples were calculated by using a Neway computer program (19).

Statistical analysis: The experiment was designed and analyzed as a repeated factorial design. If required, Duncan's multiple comparison test was applied to check whether there was a significant difference among silages (20). These analyses were performed using MINITAB and MSTAT statistical packages.

Results

The results of ANOVA indicated that the interaction between silages and incubation periods for DMD was not statistically significant ($F_{48,108} = 1.21$, $P > 0.05$). In other words, the impacts of silages on DMD did not change from period to period. However, the results of the analysis verified that there was evidence of a statistically significant difference in DMD between at least 2 silages ($F_{8,108} = 12.69$, $P < 0.01$). Therefore, Duncan's test was applied to determine which silages were significantly different from each other. The means and standard error of means of silages and the results of Duncan's test are given in Table 4. As seen in Table 4, although S5 including all the supplements had the highest DMD, there was no significant difference in DMD between S5 and S3, S4, S8 and S9.

A statistically significant difference in DMD between at least 2 incubation periods was also observed ($F_{6,108}$ =

Table 4. The means ($\bar{X}$) and standard error ($S_{\bar{X}}$) of means of DMD of silages (%).

Silages	S1	S2	S3	S4	S5	S6	S7	S8	S9
$\bar{X}$	50.64^{de}	49.45^{e}	55.66^{abc}	$58..20^{a}$	59.24^{a}	53.76^{bcd}	52.16^{cde}	57.04^{ab}	55.88^{abc}
	±	±	±	±	±	±	±	±	±
$S_{\bar{X}}$	3.08	3.49	2.97	3.04	3.15	2.66	3.10	3.28	3.10

Means with the same superscripts are not significantly different from each other ($P < 0.01$).

843.9, $P < 0.01$). The results of Duncan's test showed that all the incubation periods were significantly different from each other in terms of DMD ($P < 0.01$). The means and standard error of means of the incubation periods and the results of Duncan's test are presented in Table 5.

The impacts of different supplements on a, b, c, a + b, Pe (2%), Pe (5%) and Pe (8%) values were also evaluated by variance analysis technique. The results of the analysis for a, a + b, Pe (2%), Pe (5%) and Pe (8%) confirmed that there was a statistically significant difference between at least 2 silages ($P < 0.01$). The means and standard error of means of the DMD characteristics and the results of Duncan's test are presented in Table 6.

Discussion

Even if the results obtained in this study showed that high quality silage can be prepared without any supplements if maize is harvested at the milk dough stage (1-3), it is known that the addition of supplements and wilting result in an increase in DM in silage (2).

The analyses also verified that the addition of molasses and cracked barley caused a decrease in CP, an increase in pH and a suitable environment for fermentation (6-9). The findings in this study indicated that supplementation with molasses positively influenced fermentation and increased the Fleig point, which agreed with the results in the literature (10).

Table 5. The means ($\bar{X}$) and standard error ($S_{\bar{x}}$) of means of incubation periods (%).

Incubation Periods	4	8	16	24	48	72	96
$\bar{X}$	36.17^{g}	39.78^{f}	46.56^{e}	53.83^{d}	62.76^{c}	69.44^{d}	74.15^{a}
	±	±	±	±	±	±	±
$S_{\bar{x}}$	0.82	0.83	0.75	0.83	0.85	0.84	0.92

Means with the same superscripts are not significantly different from each other ($P < 0.01$).

Table 6. The means and standard error ($\bar{X} \pm S\bar{x}$) of means of the DMD characteristics of silages.

Silages	a (%)	b (%)	c (hour^{-1})	a+b (%)	Pe(2%) (%)	Pe(5%) (%)	Pe(8%) (%)	RSD
S1	25.53b ± 1.46	44.33 ± 4.86	0.034 ± 0.004	69.82^{b} ± 4.27	52.30^{d} ± 0.95	42.73^{de} ± 0.29	38.13^{bc} ± 0.58	1.947
S2	25.64b ± 2.39	59.89 ± 1.27	0.017 ± 0.004	85.50^{ab} ± 3.52	52.63^{d} ± 0.68	40.67^{e} ± 0.13	36.10^{c} ± 0.61	1.793
S3	34.84^{a} ± 1.58	47.18 ± 3.50	0.021 ± 0.004	82.00^{ab} ± 2.40	58.23^{abc} ± 1.11	48.30^{ab} ± 1.36	44.30^{a} ± 1.36	2.02
S4	36.31a ± 1.34	48.29 ± 3.11	0.022 ± 0.005	84.71^{ab} ± 3.34	60.83^{a} ± 1.12	50.67^{ab} ± 1.16	46.50^{a} ± 0.95	2.183
S5	37.22^{a} ± 0.94	50.73 ± 2.52	0.02 ± 0.002	91.23^{a} ± 2.56	62.00^{a} ± 0.49	51.30^{a} ± 0.72	47.03^{a} ± 0.79	1.263
S6	35.43^{a} ± 0.47	42.43 ± 6.91	0.021 ±0.005	77.82^{ab} ± 7.11	56.03^{bcd} ± 1.48	47.27^{bc} ± 0.44	43.77^{a} ± 0.19	2.043
S7	17.13^{c} ± 3.12	46.71 ± 3.74	0.032 ± 0.009	73.84^{ab} ± 3.94	54.70^{cd} ± 1.17	44.57^{cd} ± 0.38	39.93^{b} ± 0.27	1.61
S8	31.02^{ab} ± 1.41	49.29 ± 2.10	0.029 ± 0.006	80.30^{ab} ± 3.08	59.73^{ab} ± 0.27	48.87^{ab} ± 0.22	44.00^{a} ± 0.06	1.19
S9	31.31^{ab} ± 3.33	47.06 ± 3.67	0.031 ± 0.009	78.35^{ab} ± 3.27	58.40^{abc} ± 0.79	48.33^{ab} ± 1.45	43.80^{a} ± 1.74	2.507

Means with the same superscripts are not significantly different from each other ($P < 0.01$).

When urea was used as a supplement, an increase in pH and CP were achieved. There was, however, a decrease in crude fiber (13). As seen in Table 1, the quality levels of S1, S5, S6 and S7 were higher than the others. Although in the literature it is reported that fermentation was negatively affected by the addition of 0.5% urea, the positive effects of 1% urea on fermentation were observed in this research (9).

The addition of cracked barley resulted in a slight decrease in silage quality. However, an increase in the nutritional value of silages was obtained (3).

The results given in Table 4 confirmed that the use of salt as a protector did not significantly affect DMD. However, silage prepared without salt caused lower DMD than the others, except for S1 and S7 ($P < 0.01$). The silage including all supplements (S5) had the highest DMD. However, the differences among S5 and S3, S4, S5, S8 and S9 were not statistically significant. Even if S3, S6, S7 and S9 did not differ significantly from each other (Table 4), the addition of only molasses (S7) reduced DMD. The use of urea as a supplement (S6) increased DMD compared with S1 and S2, which agreed with the findings in the literature (12). The means of DMD for 4, 8, 16, 24, 48, 72 and 96 h were 36.17%, 39.78%, 46.56%, 53.83%, 62.76%, 69.44% and 74.15%, respectively. From the calculated means of DMD for incubation periods, an important conclusion to be drawn is that DMD persists through the incubation period of 96 h. No studies on the degradability characteristics (a, b, a + b, c and Pe) of silages with supplements have been found. However the results in this research were similar to those observed for silages without supplements (13-16).

The a values of silages varied between 17.23% and 37.22%. The lowest a avalue was observed for S7, which was significantly different from the others (Table 6). These values were similar to those in the literature (13-16).

The b and c values ranged from 42.43% to 59.89%, and from 0.017 to 0.034, respectively. Regarding these characteristics, there were no statistically significant discrepancies among the silages (Table 6). These results are also similar to those in the literature (13-16).

The a + b values of silages ranged between 68.82% and 91.23%. With respect to a + b values, there was a significant difference only between S5 and S1 (Table 6).

The fact that there was no significant difference in Pe (2%), Pe (5%) and Pe (8%) between S1 and S2 confirmed that the use of salt as a protector did not impact on the Pe (2%) value (Table 6).

In conclusion, the addition of all the supplements taken into consideration in this study positively affected DMD. The use of salt as a protector did not impact on DMD. From a practical point of view, the addition of molasses caused an increase in DMD. However, the statistical analysis showed that this increment was not statistically significant when compared with S1 and S2.

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