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RESEARCH ARTICLE

Fermentation Characteristics of Maize Silages Ensiled with Lactic Acid Bacteria and the Effect of Inoculated Baled Maize Silages on Lamb Performance

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Summary

The effects of homofermentative and heterofermentative lactic acid bacteria (LAB) on fermentation characteristics of maize silage and lamb performance were investigated. Maize, harvested at milk line stage of maturity, treated with homofermentative LAB or *L. buchneri,* a heterofermentative LAB, at $1.0x10^4$, $1.0x10^5$ and $1.0x10^6$ colony forming units/g (cfu/g) of herbage and ensiled in mini silos for 42 days. Only the highest level of homofermentative LAB produced silage with a more homolactic fermentation profile, whereas application of *L. buchneri* at $1.0x10^5$ cfu/g produced silage with a more heterolactic fermentation profile. This effect was more pronounced with increasing rate of *L. buchneri*. However, silage treated with the highest level of *L. buchneri* tended (P=0.06) to have lower dry matter recovery. Baled maize silages were treated with homofermentative LAB or *L. buchneri* at $1.0x10^6$ cfu/g before ensiling. Homofermentative LAB had no (P>0.05) effect on preservation characteristics of baled maize silages. However, application of *L. buchneri* increased the concentration of acetic acid (P<0.05) and aerobic stability (P<0.01) of baled maize silage. There was no (P>0.05) treatment effect on any variables measured on lamb performance. It can be concluded that treating maize with *L. buchneri* increases the aerobic stability of baled maize silage through the accumulation of acetic acid and elevated acetic acid in well fermented silages does not depress the dry matter intake.

Keywords: *Homofermentative lactic acid bacteria, Lactobacillus buchneri, Maize silage, Lamb*

Laktik Asit Bakterileri ile Silolanmış Mısır Silajının Fermantasyon Özellikleri ile Balyalanmış Mısır Silajlarının Kuzu Performansına Etkileri

Özet

Bu çalışmada homofermantatif ve heterofermantatif laktik asit bakterilerinin (LAB) süt olum döneminde hasat edilmiş mısır silajının fermantasyon özellikleri ile kuzularda performans üzerine olan etkileri araştırılmıştır. Mini silolarla yapılan çalışmada, mısır homofermantatif LAB ya da heterolaktik bir LAB olan *L. buchneri* ile $1.0x10^4$, $1.0x10^5$ ve $1.0x10^6$ cfu/g düzeyinde muamele edilerek 42 gün süre ile silolanmıştır. Sadece en yüksek düzeyde homofermantatif LAB ile muamele edilmiş silajlar daha homolaktik bir silaj fermantasyonu neticesinde üretilmiş silaj özellikleri gösterirken, $1.0x10^5$ cfu/g düzeyinde *L. buchneri* ile muamele edilmiş silajlar heterolaktik bir silaj fermantasyonu neticesinde üretilmiş silaj özellikleri göstermiş, bu etki *L. buchneri*'nin artan düzeyi ile daha belirgin olmuştur. Ancak $1.0x10^6$ cfu/g düzeyinde *L. buchneri* muamelesi ile kuru madde kazanımları azalma (P=0.06) temayülü göstermiştir. Balyalanmış mısır silajları homofermantatif LAB ve *L. buchneri* ile silolama öncesinde $1.0x10^6$ cfu/g düzeyinde muamele edilerek hazırlanmıştır. Homofermantatif LAB ilavesinin balyalanmış silajların fermantasyon özellikleri üzerine etkisi önemsiz (P>0.05) bulunmuştur. Bununla beraber, *L. buchneri* ile muamele edilmiş balyalanmış silajların asetik asit içeriği (P<0.05) ile aerobik stabilitesi (P<0.01) artmıştır. Kuzuların performansı üzerine muamelelerin etkisi önemsiz (P>0.05) bulunmuştur. Araştırma sonucunda *L. buchneri* ilavesi ile balyalanmış mısır silajının aerobik stabilitesinin, silajın artan asetik asit içeriğine bağlı olarak arttığı ve iyi fermente olmuş silajların içerdiği yüksek asetik asidin kuru madde tüketimini etkilemediği değerlendirilmiştir.

Anahtar sözcükler: *Homofermantatif laktik asit bakterileri, Lactobacillus buchneri, Mısır silajı, Kuzu*

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INTRODUCTION

Fundamental of efficient ensiling of crops is the rapid achievement of anaerobic conditions together with the inhibition of the activity of undesirable anaerobic micro-organisms [1]. However, silage fermentation is not a controlled process and conditions are not always optimal to ensure satisfactory fermentation. The application of silage additives during ensiling is sometimes used to encourage beneficial microbial activity and/or inhibit detrimental microbial activity. It is possible to use both chemical and biological additives in silages making, in order to promote adequate fermentation patterns, especially under sub-optimal condition. Bacterial inoculants have advantages over chemical additives because they are safe, easy to use, non-corrosive to machinery, do not pollute the environment, and are regarded as natural products. Homofermentative lactic acid bacteria (LAB) have been widely used in silage inoculants because they are fast and efficient producers of lactic acid (LA) [2]. However, studies have shown that homofermentative LAB could decrease aerobic stability of silages and result in increased aerobic deterioration of silages at feedout [3-5]. This is because homolactic silages are often characterized by having low levels of volatile fatty acids [6] and ammonia [7], which have an inhibitory effect against yeast and moulds. Another current challenge in use of homofermentative LAB is the reported lack of effectiveness in maize silage which has already good ensiling characteristics with a low buffering capacity, low crude protein, and relatively high dry matter (DM) and water soluble carbohydrates (WSC) [8,9].

Lactobacillus buchneri, a heterofermentative lactic acid bacterium, alone or in combination with homofermentative LAB has been showed to increase the aerobic stability of silages through the accumulation of acetic acid [10]. However, compared to homolactic fermentation, heterolactic fermentation could be considered disadvantageous because of the formation of water and gas during the fermentation of sugar to fermentation acids [1]. As a result, DM losses can increase and this value can multiply when a high rate of heterolactic LAB is applied to the maize forage [11,12]. Another challenge in using *L. buchneri* as a silage additive is that high level of acetic acid could suppress the DM intake (DMI) in ruminants [13,14].

Few studies have been conducted simultaneously comparing the responses to homofermentative LAB and *Lactobacillus buchneri* for baled maize silages that were fed to lambs. The objective of this experiment was to assess the effects of homofermentative LAB and *L. buchneri* on final fermentation products of maize silage either in mini silos or in baled silages. Their effect on DMI and live weight gain (LWG) of lambs fed with the homofermentative LAB or *L. buchneri* inoculated baled maize silages was also investigated.

MATERIAL and METHODS

Mini Silos

Whole plant maize was harvested at milk line stage of maturity by using a conventional forage harvester (Sezer, Bandirma, Turkey) to a theoretical chop length of 1.0-2.0 cm. Seven randomly selected 8 kg material were then treated with the following additive treatments: (1) control - no additive (C), (2) homofermentative LAB (HM4; Pioneer® 1132, *L. plantarum, E. faecium,* Pioneer® Hi-Bred, Int., Inc., USA) applied at $1.0x10^4$ colony forming units (cfu)/g herbage, (3) same bacteria used in treatment 2 applied at $1.0x10^5$ cfu/g herbage (HM5), (4) same bacteria used in treatments 2 and 3 applied at $1.0x10^6$ cfu/g herbage (HM6), (5) hetero-fermentative LAB (LB4; Pioneer® 11A44, *L. buchneri,* Pioneer® Hi-Bred, Int., Inc., USA) applied at $1.0x10^4$ cfu/g herbage, (6) same bacteria used in treatment 5 applied at $1.0x10^5$ cfu/g herbage (LB5), (7) same bacteria used in treatments 5 and 6 applied at $1.0x10^6$ cfu/g herbage (LB6). All bacterial inoculants, in powder form, were dissolved in 20 ml of deionised water and spread evenly (in a uniform manner with constant mixing) over each 8 kg herbage sample with a hand sprayer. The same amount of deionised water was also added to the control treatment. Approximately 1.7 kg material was ensiled in each mini-silo (i.e. 1.5-L polyethylene anaerobic jar) using a press machine. The DM densities of jars were 323 kg/m^3. A total of 28 mini silos were used providing quadruplicate for each treatment. Silos were weighed before and after filling and then stored for 42 days at ambient temperature (22±2°C).

Baled Maize Silage

Whole-maize was harvested 3 days after harvesting for mini-silos using same harvester to a theoretical chop length of 1.0-2.0 cm. Three wagons were loaded with 2.2 t of chopped maize and then each wagon was randomly assigned to one of the following additive treatments: (1) control - no additive (C), (2) homofermentative LAB used in mini silos applied at $1.0x10^6$ cfu/g of herbage (homo-fermentative LAB), (3) heterofermentative LAB used in mini silos applied at $1.0x10^6$ cfu/g of herbage (*L. buchneri*). The additives were spread in sequence on the chamber of bale wrapper combi for maize (Göweil, Maschinenbau GmbH, Germany). The bacterial inoculants were dissolved in 4 L of chlorine free water and spread evenly over the 2.2 t forage. The same amount of water was also spread on control treatment.

Two round bales (1.25 m diameter and 1.25 m width) were produced in each treatment. Another round bale was also produced between each LAB treatment to prevent microbial contamination. A total of seven bales were wrapped with six layers of white plastic stretch-film, weighed and transported for storage on their curved side, under a shelter to prevent wild life damage and exposure to the elements.

Bales opened at 42 days of ensiling and sampled for DM, pH, WSC, LA and volatile fatty acids [VFAs; acetic (AA), propionic (PA) and butyric acid (BA)].

Aerobic stability of the baled silages was also assessed. Approximately 1 kg silage sample from each bale was placed loosely in a 5-L jar. A layer of cheesecloth was placed over the jar and silage was exposed to air at ambient temperature (22±2°C). The temperature of the silage mass and ambient temperature was recorded by a data logger (CR1000, Campbell Scientific, Inc., Logan, Utah, USA), adjusted to record every 10 min and averaged over a period of every 2 h. The index of AS was expressed as the interval in hours until the temperature of silage mass rose more than 2°C above ambient temperature.

Feeding Trial

The feeding trial consisted of a 12 days acclimatization period followed by six weeks of an experimental period. Thirty three Konya merino female lambs, with an average initial live weight of 38.4±2.2 kg, were housed in pens (1.7x1.5 m) with individual waterers and feeders. Lambs were acclimatized to silage by gradually changing their diets from pasture to silage. In this period all lambs were fed with baled silage without additives. They were then randomly divided into three groups for the control, homofermentative LAB and *L. buchneri* treatments. Silages were offered *ad libitum* in experimental period. Dry matter intake was determined daily. A concentrate (2550 metabolizable energy kcal/kg, 16.1% crude protein) equivalent to 1% of individual live weights of lambs was also given. Lambs were weighed on two consecutive days for every two weeks.

Analytical Procedures

Fresh and silage samples were assayed for DM by oven drying at 60°C for 48 h. Twenty g of sampled herbage were blended with 180 ml of distilled water (Waring Blender, 8010ES, US) for 1 min at high speed. The resulting homogenate was filtered through Whatman 1 filter paper. The pH of the filtrate was measured with a pH meter (WTW, Inolab 720, Germany). A proportion of the filtrate (50 ml) was acidified with 100 µm of 50% H_2SO_4, centrifuged at 6.000 x *g* for 15 min and then frozen, before being used for determination of concentration of LA [15] and WSC [16]. A further proportion of the filtrate (5 ml) was acidified with 1 mL meta-phosphoric acid (vol/vol, 25%), centrifuged at 4.000 x *g* for 10 min and then frozen prior to analysis for VFAs concentration. Volatile fatty acids were measured by gas chromatography (GC-15A, Shimadzu, Kyoto, Japan) according to Supelco [17]. Fermentation products (FP) was the sum of the total measured fermentation products (i.e. LA + AA + PA + BA).

Statistical Analysis

All data from silage composition and feeding trial were analyzed by one-way analysis of variance (ANOVA) in a completely randomized design, using the general linear model procedure of Minitab 10 [18]. Comparisons between treatments were made using the least significant difference procedure.

RESULTS

Mini Silos

The DM and DM recovery (DMR), and chemical composition results are presented in *Table 1*. There was no (P>0.05) treatment effects on DM at the end of 42 day ensiling period. However, silage treated with LB6 tended (P=0.06) to have a lower DMR.

Table 1. *Dry matter recovery and chemical composition (DM bases) of maize silages ensiled in mini silos*
Tablo 1. *Mini silolara silolanmış mısır silajlarının kuru madde kazanımları ve kimyasal kompozisyonları (KM'de)*

Variable [2]	FC	Treatments [1]							s.e.m.	Sig [3].
		C	HM4	HM5	HM6	LB4	LB5	LB6		
DM, %	28.5	28.0	28.4	28.4	27.8	28.2	27.8	27.4	0.32	NS
DMR, %	-	93.4	94.8	94.8	92.3	94.1	92.3	90.4	1.03	NS
pH	5.8	3.74^{c}	3.75^{bc}	3.78^{b}	3.75^{bc}	3.75^{bc}	3.76^{bc}	3.82^{a}	0.012	***
Lactic acid, %	0.05	6.90^{ab}	5.87^{bc}	6.49^{bc}	8.51^{a}	5.91^{bc}	5.30^{bc}	4.60^{c}	0.68	*
Acetic acid, %	0.24	2.06^{c}	1.72^{cd}	1.50^{cd}	0.96^{d}	1.86^{cd}	3.80^{b}	4.81^{a}	0.31	***
Propionic acid, %	0.04	0.06	0.03	0.02	0.04	0.06	0.05	0.06	0.02	NS
Butyric acid, %	0.02	0.08	0.06	0.05	0.06	0.04	0.02	0.05	0.02	NS
WSC, %	7.7	1.81^{a}	1.68^{ab}	1.66^{ab}	1.81^{a}	1.44^{ab}	1.13^{b}	0.37^{c}	0.20	***
LA/AA	-	3.55^{b}	3.51^{b}	4.42^{b}	8.94^{a}	3.36^{b}	1.53^{c}	0.98^{c}	0.55	***
FP, %	-	9.10	7.67	8.05	9.57	7.88	9.17	9.53	0.71	NS
LA/FP	-	74.8^{b}	74.9^{b}	80.5^{ab}	89.0^{a}	74.7^{b}	58.6^{c}	48.5^{d}	3.16	***

[1] FC=fresh composition; C=control; HM4=homofermentative LAB (1.0x10⁴ cfu/g); HM5=homofermentative LAB (1.0x10⁵ cfu/g); HM6= homofermentative LAB (1.0x10⁶ cfu/g); LB4=L. buchneri (1.0x10⁴ cfu/g); LB5= L. buchneri (1.0x10⁵ cfu/g); LB6= L. buchneri (1.0x10⁶ cfu/g)
[2] DM=dry matter; DMR=dry matter recovery; WSC=water soluble carbohydrates; LA/AA=proportion of LA to AA; FP=total measured fermentation products; LA/FP=proportion of LA in FP
*[3] NS= not significant (P>0.05); *=P<0.05; ***=P<0.001*

The application of both HM5 and LB6 resulted in a slight increase (P<0.001) in silage pH, while a decrease (P<0.05) in LA concentration occurred only for the LB6, compared with the control silage. None of the fermentation characteristics were altered by HM4 and HM5 or LB4. The exception was that HM5 decreased the silage pH. Concentration of AA was lower (P<0.001) in silage treated with HM6 compared to the control silage but it was higher (P<0.001) in silages treated with LB5 and LB6, with the concentration being the highest (P<0.001) for the LB6. There was no (P>0.05) treatment effects on the concentration of PA, BA, or on total measured FP produced. Silage treated with LB5 had a lower (P<0.001)WSC concentration compared to the control silage but the reduction in WSC concentration with the application of LB6 was the highest (P<0.001). The LA/AA ratio was the highest (P<0.001) in silage treated with HM6, whereas silages treated with LB5 and LB6 had the lowest (P<0.001) value in this variable. Silages treated with HM6 additive had also a higher (P<0.05) value on proportion of LA to other measured fermentation product (LA/FP) compared to the control silage. However, silages treated with LB5, in particular LB6 had the lowest (P<0.001) LA/FP ratios.

Baled Maize Silages and Feeding Trial

The mean (s.d.) fresh and DM weights of seven bales at ensiling were 1.056 (24.0) and 269 (9.0) kg, respectively. The DM densities of bales were 176 kg/m^3.

The chemical composition and aerobic stability of baled maize silages are presented in *Table 2*. The treatments had only a significant effect on silage pH, concentration of AA and aerobic stability of baled silages. The application of homofermentative LAB and *L. buchneri* caused a slight increase (P<0.05) in silage pH. The application of *L. buchneri* also increased concentration of AA (P<0.05) and aerobic stability of maize silage (P<0.01).

The results of the feeding experiment are presented in *Table 3*. The total concentrate intake of lambs over the

Table 2. *Chemical composition (DM basis) and aerobic stability of baled maize silages*
Tablo 2. *Balyalanmış mısır silajlarının kimyasal kompozisyonları (KM'de) ve aerobik stabiliteleri*

Variable [2]	FC	Treatments [1]			s.e.m	Sig [3].
		C	HM LAB	LB		
Dry matter, %	26.6	25.3	26.3	25.5	0.53	NS
pH	5.8	3.76^b	3.83^a	3.85^a	0.01	*
Lactic acid, %	0.34	9.45	10.3	9.09	1.19	NS
Acetic acid, %	0.13	3.68^b	2.87^b	5.59^a	0.38	*
Propionic acid, %	0.04	0.14	0.09	0.20	0.02	NS
Butyric acid, %	0.02	0.27	0.12	0.15	0.08	NS
WSC, %	8.7	0.36	0.41	0.25	0.03	NS
LA/AA	-	2.58	3.63	1.64	0.46	NS
FP, %	-	13.5	13.4	15.0	1.22	NS
LA/FP	-	69.3	76.9	60.6	3.40	NS
Aerobic stability, h	-	83^b	69^b	116^a	3.97	**

[1] FC=fresh composition; C=control; HM LAB=homofermentative LAB (1.0x10^6 cfu/g); LB =L. buchneri (1.0x10^6 cfu/g)
[2] DM=dry matter; WSC=water soluble carbohydrates; LA/AA=proportion of LA to AA; FP=total measured fermentation products; LA/FP=proportion of LA in FP
*[3] NS= not significant (P>0.05); *=P<0.05; **=P<0.01*

Table 3. *Performance of lambs fed with the baled maize silages*
Tablo 3. *Balyalanmış mısır silajları ile beslenen kuzuların performansları*

Variable [2]	Treatments [1]			s.e.m	Sig [3].
	C	HM LAB	LB		
Weight of lambs at day 0, kg	38.6	38.7	38.8	0.31	NS
Weight of lambs at day 42, kg	44.1	44.1	43.5	0.48	NS
Total LWG, kg	5.44	5.36	4.75	0.44	NS
Average daily LWG, g	130	128	113	10.5	NS
Total silage DMI in 42 days, kg	37.6	38.7	35.4	1.17	NS
Average daily silage DMI, g	894	922	843	27.9	NS
FCR	10.3	10.7	10.6	0.74	NS

[1] C=control; HM LAB=Fed with homofermentative LAB treated silages; LB=Fed with L. buchneri treated silages
[2] LWG=live weight gain; DMI=dry matter intake; FCR= feed conversation ratio (DMI/LWG)
[3] NS= not significant (P>0.05)

42 day feeding trial was 15.0, 15.1 and 15.1 kg for the control, homofermentative LAB and *L. buchneri* treatments, respectively. There was no (P>0.05) treatment effect on any variables measured in feeding trial.

DISCUSSION

Mini Silos

All treatments in the mini-silos produced good quality silages as evidenced by the low pH and low concentrations of BA. However, even though a similar concentration of FP was produced in all silages to reach a stable pH, the LA/AA and LA/FP ratio values indicated that a different fermentation pattern occurred among the different lactic acid bacteria treatments.

Only the highest application rate of homofermentative LAB (HM6) produced a more homolactic fermentation as evidenced by the higher proportion of LA in FP, together with having an increased LA/AA ratio. In contrast, the two lowest application rates of the homofermentative LAB did not change the fermentation end products of silages, compared to control silage which already appeared to be dominated by homofermentative lactic acid bacterial activity. These outcomes suggest that the two lowest application rate of homofermentative LAB were not sufficient enough to dominate the natural epiphytic bacterial community during the fermentation in maize silage. Under conditions where the high additive rate (i.e. HM6) resulted in a more homolactic fermentation, it was not surprising that the AA content of these silages was low. This is in agreement with the findings of Filya [4] and Ozduven et al.[5] that successful inoculation with homofermentative LAB resulted in silage with lower concentration of AA. However, despite the fact that HM6 silages underwent a more homolactic fermentation, the absence of a more DMR was unclear.

Both LB5 and LB6 silages showed evidence of well preserved silages that were dominated by heterolactic fermentation as indicated by reduced LA/AA and LA/FP ratios. This effect was more pronounced with increasing application rate of *L. buchneri*. The latter outcome in line with the findings of Ranjit et al.[19] and Filya et al.[12] who reported that increasing the application level of *L. buchneri* from $1.0x10^5$ to $1.0x10^6$ cfu/g resulted in a more heterolactic fermentation in maize silage. The WSC concentration remaining after 42 days of ensiling for LB5 and LB6 treatments showed that heterolactic fermentation used more of the available WSC compared to homolactic fermentation which is in agreement with the work reported by Ranjit and Kung [20] and Filya [21].

It was expected that silages dominated by heterolactic fermentation would have lower DMR as a nature of heterolactic fermentation. Driehuis et al.[11] and Filya et al.[12] reported that weigh losses increased with the each increment in application rate of *L. buchneri* from $1.0x10^5$ to $1.0x10^6$ cfu/g. In present study, DMR in the mini silos were not different when *L. buchneri* applied to maize at $1.0x10^5$ cfu/g, but the highest application rate of *L. buchneri* tended to reduce this variable. These findings suggested that DMR could be lower in maize silages when *L. buchneri* applied at $1.0x10^6$ cfu/g.

Baled Maize Silages and Feeding Trial

Satisfactory fermentation depends on maintaining anaerobic conditions during ensilage and on inhibiting the activity of undesirable anaerobic microorganisms [1]. In this study, the DM density of the herbage at ensiling was satisfactory and this indicated that the bales were well formed and dense. As a result, bales did not loose their shape during feeding experiment. Preservation of baled silages was also satisfactory as indicated by the relatively low silage pH, and moderately low concentration of BA with no visual mould development or aerobic deterioration on bale. Thus, these characteristics indicated that anaerobic conditions prevailed within the bales and evidence for undesirable microbial activity was quite small. The outcome suggested that when baled silages are wrapped with an adequate level of plastic stretch-film (at least four layer), the anaerobic conditions created are adequate to inhibit undesirable microbial activity provided the physical integrity of the plastic seal is maintained [22]. However higher concentration of FP and lower concentration of WSC in baled maize silages suggested that baled silages underwent a more extensive fermentation compared with silages ensiled in mini silos. It is likely that a number of factors contributed to such differences. In present work, difference in DM concentration and DM densities between mini silos and bales (28.6 and 26.6%; 323 and 178 kg/m^3, respectively) at ensiling could have been attributed to these differences.

The application of the homofermentative LAB had no benefit on the fermentation end products of baled maize silages. Sucu and Filya [9] and Ranjit and Kung [20] also reported that inoculation of maize with homofermentative LAB had lack of effectiveness on concentration of LA which is one of the most important indicators of a more homolactic fermentation. This is probably due to maize has good ensiling characteristics with a low buffering capacity and rich in WSC content. However, higher AA concentration in baled silages treated with *L. buchneri* resulted in more stable silages when exposed to air. This result is in line with the findings of Filya [21], Ranjit et al.[19], Ranjit and Kung [20] and Filya et al.[12] who reported that AA improved the aerobic stability of maize silage due to strong antifungal properties of AA [6]. These outcomes also indicated that *L. buchneri* had a more robust effect on silage fermentation of maize than homofermentative LAB did as observed by Ranjit and Kung [20].

Previous work using VFA salts such as sodium propionate or sodium acetate [13] and analyses of literature data [14] suggested that increased VFAs in silage may be associated with reductions in DMI. In the present experiment elevated AA after inoculation of *L. buchneri* in maize silage did not suppress the DMI. This is in agreement with the other experiments done with *L. buchneri* in dairy cows [23,24] and in sheep [19]. This outcome suggests that feeding silages with elevated AA alone is not responsible for depressing DMI in ruminants.

In conclusion, in mini-silos study, only the highest levels of homofermentative LAB changed the concentration of the final fermentation products of maize silage. However, more homolactic fermentation in these silages did not result in higher DMR of maize silages. Inoculation with *L. buchneri* at $1.0x10^5$ cfu/g produced silage with a more heterolactic fermentation profile, and this effect was more pronounced with increasing rate of *L. buchneri*. The DMR of silages treated with *L. buchneri* at $1.0x10^5$ cfu/g was similar to control silage or silage treated with homofermentative LAB but tended to be lower in silage treated with *L. buchneri* at $1.0x10^6$ cfu/g. In baled silages, homofermentative LAB treatments had little effect on the outcome of preservation. However, the *L. buchneri* treatment resulted in silage with a higher concentration of AA and a higher aerobic stability on exposure to air. Treating maize with *L. buchneri* had a more robust effect on the final fermentation products of maize silage than homofermentative LAB did in mini silos or in baled silages. Performance of lambs fed with the silages treated with homofermentative or heterofermentative were similar with the lambs fed with the silages with no additives. These finding indicated that treating maize with *L. buchneri* may be advantageous in changing the final fermentation products of maize silage in such a carbohydrate-rich crop particularly when silages are exposed to air.

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