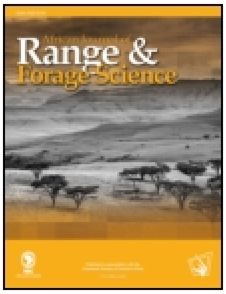

Fermentation characteristics of maize-forage legume mixtures ensiled in small-scale silos

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Abstract:	This study was conducted to evaluate the ensiling characteristics of maize-forage legume mixtures in small-scale silos. Sole and intercrops forage materials were harvested 80 days after planting and ensiled in small-scale silos, viz. plastic bags, plastic drums, and small pits for 60 days. After ensiling, samples were collected to examine the chemical composition, microbial community, and fermentation quality. Mixed silages stored in the drum silos had significantly ($p \leq 0.05$) higher DM content than that from pit and bag silos. The drum silos had significantly ($p \leq 0.05$) higher crude protein concentration in sole legume silages than other silo types. Neutral detergent fibre concentration of sole forage silages was greatest in bag silos than in other silos. High in vitro dry matter digestibility and water-soluble carbohydrate values for mixed silages were recorded in drum silos. Bag silos showed lower numbers of lactic acid bacteria and higher populations of enterobacteria in sole forage silages than other silos. Mixed silages ensiled in drum silos produced significantly lower pH and ammonia nitrogen content compared to pit and bag silos. The study concluded that ensiling maize-forage legume mixtures in drum silos can have a positive effect on the nutritive value of ruminants' feeds.

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1. Introduction

Smallholder farmers have challenges in finding adequate feed for livestock, especially in the dry season. They are forced to buy feed such as hay and concentrates to maintain animals. Silage making, albeit at a small scale, has been suggested as a way of alleviating feed shortage in the dry season (Duguma and Janssens, 2021). During ensiling green fodder is harvested at approximately 2-4 cm in length and wilted to reach the optimum moisture content (Baldini *et al*., 2017). The chopped forage material is then packed in a silo such as a plastic bag, small plastic drum and/or small pit. The silo is then tightly sealed to prevent aeration which often leads to spoilage. Silage can be kept for a long period (3-5 years) without deteriorating and still provides high-quality forage in any desired season of the year at a low expense (Coblentz *et al*., 2021). It is palatable to livestock and can be fed at any time. While several forages have been suggested as raw materials for smallholder silage making maize-forage legume mixtures offer benefits whereby maize becomes the main energy source and legumes provide a protein base (Stoltz *et al*., 2014).

Intercropping maize with forage legumes is a better approach than traditional sole maize crop or legume due to reduced inputs, (namely fertilizers), higher yields and greater resource utilization (Seran and Brintha, 2010). Morphologically, legumes and maize complement each other in intercropping systems resulting in efficient use of resources, *viz* light, nutrients and water (Maitra *et al*., 2019). In soils with low nitrogen, maize performed well because it benefited from nitrogen fixed by legumes in an intercropping system (Mandal *et al*., 2014). Forage legumes grown as cover crops in intercropping systems suppress weed growth by covering the ground, thereby helping to deliver greater productivity (Manasa *et al*., 2018).

Although maize and forage legumes are palatable and a valuable source of fodder for livestock, conservation of forage has been recognized as one of the major challenges, especially in smallholder farming systems (Philp *et al*., 2019). In the lowlands of Lesotho conserving fresh forage in the form of silage is not common, and haymaking is used as the traditional method of forage conservation on smallholder farms. Haymaking operations on smallholder farms are associated with several constraints such as slowness of drying forage materials under humid conditions, shattering of the vegetative parts of the forage under dry and hot conditions, mechanical forage leaf loss during field handling, and further mechanical loss during collection, transport and baling of forage materials (Rotz *et al*., 2020).

In this context, silage making is a viable alternative method of forage conservation because it is not dependent on weather conditions. The shorter curing time of silage may allow crops to be cut earlier with a reduced risk of weather damage compared with hay (Usman *et al*., 2021). Silage making preserves more of the nutritional value of the crop, whereas hay making preserves a significantly lower percentage of nutrients (Ojo *et al*., 2017). Hay needs to be processed to obtain a uniformly mixed ration while silage is better suited as an ingredient in mixed rations for livestock. Silage making ensures a more palatable and digestible feed, which improves animal performance (Santos *et al*., 2014). Conserving forage as silage allows the conservation of large quantities of forage in a short time and lower nutrient loss (Tamir *et al*., 2012), relative to traditional hay making. However, conventional large-scale silage making is beyond the reach of smallholder farmers in terms of equipment, labour intensiveness and high production levels.

Small silos such as plastic bags, plastic drums and/or pits can be an economical alternative to large pits/silos. They all allow farmers to store silage anywhere they need it. The silage is completely sealed in the small silo such that all the acid is retained in the silage. Whole small silo can be fed out to the animal and the rest of the silage remains in the other silos not exposed to air. Small silos are easy to pack and store and are portable, any member of the family can carry them to the feed trough for animals. They are watertight and prevent precipitation from reaching the ensiled crops (Carrizo *et al*., 2011). These silos also allow for other products, such as additives or preservatives, to be added to prepare a more complete feed source (Chen *et al*., 2020). However, all these potential benefits of maize-legume mixtures and small-scale silos assume sound fermentation and preservation under smallholder conditions. To help guide adoption of small-scale silo technologies there is a need to study the ensiling patterns of forage mixtures. The high buffering capacity of forage legumes has potential to extend fermentation and increase protein breakdown (Bolson *et al*., 2022). This is in addition to the potential variability in fermentation patterns of different legumes alone or in mixtures with maize (Kintl *et al*., 2020). The present study was conducted to evaluate the ensiling characteristics of mixtures of maize and common vetch or lablab in small-scale silos.

2. Materials and methods

2.1. Study site

A field experiment was conducted at Thaba-Bosiu (29° 22´ 3S, 27° 40´ 59 E and altitude 1804 m asl) where maize (*Zea mays* L.) was intercropped with common vetch (*Vicia sativa* L.) or lablab (*Lablab purpureus*) under rainfed conditions for two years (2020-2021). The site lies in a lowland region of Lesotho characterised by warm summers and cold winters. Rainfall ranges from 500 mm to 1000 mm per annum, with the highest values in the summer season (Lesotho Meteorological Services, 2023). Winters are generally dry and cold and are characterized by dry air and warm to moderate temperatures during the day, with a sudden cold temperature just after sunset. The average annual temperature ranges between 15.2°C and 25.6°C in the lowland region. The predominant soils of the area are classified as humic soils with an orthic A horizon (Fey, 2010).

2.2. Agronomic practices

Maize, lablab and common vetch were grown as sole crops or as maize with a legume cover crop in 10 x 5 m plots replicated three times. A basal fertilizer (6:3:4 NPK) was applied to all maize plots at a rate of 75 kgha^{-1} at sowing. Legume only plots received a combination of P and K at 80 kgha^{-1}. The plant density of maize was 40 000 plants/ha and the forage legumes (lablab and common vetch) were planted at 60,000 plants/ha. All necessary agronomic practices (weed, pest and disease control) were kept uniform for all experimental plots during the cropping season. A one-meter-long row from each plot was harvested at ground level for silage making. Maize and forage legume samples were harvested at 80 days of age, and the chemical composition of forage samples was assessed directly prior to ensiling.

2.3. Silage preparation

Silage was prepared from sole maize (MZ), sole common vetch (CV), sole lablab (LB), and in mixtures of maize + common vetch (MZ + CV) and maize + lablab (MZ + LB) from the intercrops. The forage material was ensiled in three types of small-scale silos, *viz.* plastic bags (790 x 950 x 30 micron), 50 litre plastic drums and small pit (150 x 200 x 300 cm). The harvested forage materials were wilted overnight to reduce moisture content to 50 – 45%. The maize and legume materials were chopped to lengths of approximately 3-4 cm using a forage cutter. The forage materials were ensiled in the small-scale silos to a capacity of 20.0±0.5 kg. Once filled with forage material, the small-scale silos were compacted using a pressing apparatus to expel air as much a was possible to ensure sustainable anaerobic conditions. The experiment was designed as a completely randomized design with a 5 (forages) x 3 (silos) factorial treatment arrangement and three replicates. The small-scale silo bags and drums were then incubated at room temperature (±25 – 30°C) for 60 days. The pit silos were also incubated for 60 days and their temperatures averaged 25°C.

2.4. Silage fermentation profiles

The silages were evaluated after 60 days of ensiling. Samples were collected and freeze dried using an Alpha 1-4 LSC freeze drier (Martin Christ Freeze Dryer, Germany) at −60 °C and at a pressure of 0.011 mbar for 24 hours. Dried samples were ground in a laboratory mill (Thomas Wiley model 4, Arthur Thomas & Co.) with a 1 mm screen and stored for chemical analysis. Crude protein (CP) was determined using AOAC (2000) procedures; neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents following the Van Soest *et al*. (1991) method; and *in vitro* dry matter digestibility (IVDMD) using the Tilley and Terry (1963) method.

Microbial populations and pH of the silages were measured on the day of silo opening. Immediately after opening the small-scale silos, 40 grams of each fresh silage sample was weighed and placed into a sealable container with 350 ml of distilled water. The container was closed and shaken for 6 h at 180 rpm using a horizontal shaker. The silage extract was then filtered through four layers of cheesecloth directly after sample preparation. An electrode pH meter in a water-based solution was used to measure pH. The plate culture method was used to determine microbial populations of the fresh silages. Twenty grams of each sample was weighed and shaken well with 100 ml of sterilized distilled water and diluted in a sodium chloride solution (0.90%). Lactic acid bacteria (LAB) were counted on an agar plate of Lactobacilli MRS broth after incubation in an anaerobic box at 40°C for at least 24 hours. Enterobacteria were determined on a plate of violet red bile agar with lactose after anaerobic incubation at 35°C for 24 hours. Yeast and mould (Y&M) were counted on potato dextrose agar plates after incubation at 30°C for 24 hours. For analysis of the microbial population, colonies were counted, and their numbers were expressed as viable numbers of microorganisms in colony forming units per gram of fresh matter (CFUg-^{1}) and transformed into $\log_{10}$ of CFUg-^{1}.

For lactic acid and VFA analysis silage extracts (2 ml) were filtered and acidified with meta-phosphoric acid (25%) to reduce the pH of the extracts. Samples were then centrifuged for 15 min using a capillary column over a temperature of 40°C to determine lactic acid and volatile fatty acid concentrations, including acetic acid, butyric acid and propionic acid (Khorvash *et al*., 2006). Silage extracts (25 ml) were placed in a stomacher blender for 3 min and filtered through Whatman filter paper to determine silage ammonia nitrogen (NH_3-N) (Filya, 2002). Total fatty acid (TFA) content was determined using AOAC (2000) procedures, and water-soluble carbohydrate (WSC) by colorimetry after reaction with anthrone reagent (McDonald *et al*., 1991).

2.5. Statistical analysis

Analyses of variance were performed on the data using the general linear model (GLM) procedures of the Statistical Analysis System (SAS 2013). Variance was apportioned to type of silo, forage type, and their interaction. The dependent variables were chemical composition, microbial populations and fermentation characteristics. Treatment means were compared using a protected LSD $_{(p<0.05)}$ test.

3. Results

3.1. Forage and silage chemical composition

The chemical composition of forages prior to ensiling is presented in Table 1. The dry matter (DM) for the forages ranged from 17.86 to 37.61%, and the mixtures had higher values than sole forages. The CP content varied from 6.12 to 23.69% DM and the sole legume forages had higher levels than the other forages. The NDF concentration ranged from 31.03 to 45.47% DM. Across mixtures, NDF concentration was (32.45% DM) lower than sole forages (41.58% DM). The ADF content varied between 32.04 to 47.60% DM and the lowest values were found in sole forages. MZ+LB and MZ+CV had the highest IVDMD of 59.57 and 58.18 % DM, respectively, followed by LB (56.48% DM), CV (55.38% DM), and MZ (55.07% DM). The WSC and TFA contents ranged from 7.36 to 11.44 and 1.24 to 4.94% DM, respectively; the highest and lowest values were observed in mixtures and sole legumes, respectively.

The chemical composition of the silages is presented in Table 2. For the silo types, the DM and CP contents ranged from 15.61 to 37.12 and 7.14 to 23.38% DM, respectively. The highest and lowest values of DM content were found in drum and bag silos, respectively, and the CP content also showed a similar trend. The DM and CP contents in the forage systems varied from 16.64 to 36.35% and 6.99 to 22.95% DM, respectively. MZ+LB and MZ+CV silage mixtures had greater DM content and the lower values were recorded in sole forage silages. Sole CV and LB forage silages had higher CP concentrations than MZ+LB, MZ+CV mixtures and sole MZ forage silages. Different silos showed significant effects on DM and CP contents for mixed crop silages. Silages stored in the drum silos had significantly higher DM values ($p \leq 0.05$) than that from pit and bag silos. CP values were significantly higher ($p \leq 0.05$) in drum silos, intermediate in pit silos and lowest in bag silos.

The NDF and ADF contents of the silages varied from 25.76 to 44.73 and 16.41 to 42.03% DM, respectively. NDF and ADF concentrations of the drum silos were less than those of pit and bag silos. The NDF and ADF across forage systems ranged from

29.27 to 40.40 and 20.67 to 40.42% DM, respectively. MZ+LB mixed silage had lower NDF than sole forage silages. The ADF concentrations of sole legume forage silages were lower compared to those of mixed silages. The silo type × forage systems interaction for NDF and ADF measures was statistically significant ($p \leq 0.05$). NDF and ADF concentrations of sole forage silages (MZ, LB and CV) were greatest in bag silos, intermediate in pit silos and lowest in drum silos.

The IVDMD, WSC and TFA ranged from 43.93 to 58.84, 6.26 to 12.55 and 1.71 to 5.87% DM across silo types, respectively. Bag and pit silos had lower ($p \leq 0.05$) IVDMD, WSC and TFA values than drum silos. Across forage systems, the IVDMD, WSC and TFA values varied from 50.01 to 57.93, 6.65 to 12.01 and 2.06 to 5.35 % DM respectively. MZ+LB and MZ+CV mixed silages had higher ($p \leq 0.05$) IVDMD WSC and TFA values than sole MZ, sole LB and sole CV forage silages. Different silo types and forage systems showed significant effects on IVDMD, WSC and TFA for forage silages. High IVDMD, WSC and TFA values for MZ+LB and MZ+CV mixed silages were recorded in drum silos, while intermediate values in pit silos and low in bag silos. Sole forage silages also showed a similar trend across silo types.

3.2. Silage microbial composition

The count of microbial colonies in the silages is presented in Figure 1. The LAB, ENT and YM across silo types ranged from 4.96 to 5.05, 3.62 to 3.73 and 3.94 to 4.05 $\log_{10}$ cfug^{-1}, respectively. Drum silos showed higher ($p \leq 0.05$) growth of LAB compared to pit and bag silos. ENT count in bag silo was higher than pit and drum silos. The lowest mould and yeast (YM) count was observed in drum silo followed by pit and bag silos. The LAB, ENT and YM across forage systems ranged from 4.41 to 5.31, 3.24 to 4.57 and 3.77 to 4.31 $\log_{10}$ cfug^{-1}, respectively. Higher LAB count was observed in MZ+LB and MZ+CV mixed silages compared to sole forage silages. The ENT and YM counts were higher in sole forage silages than in mixed silages. The interaction of silo types and forage systems had significant effects on the population of LAB, ENT and YM. Drum silos showed higher numbers of LAB and lower populations of ENT and YM in MZ+LB and MZ+CV mixed silages than the other silo types.

3.3. Silage fermentation characteristics

The fermentation characteristics of the silages are presented in Figure 2. The pH of silages from the different silo types ranged from 3.23 to 4.13, NH_3-N 5.82 to 8.27% TN and lactic acid 1.18 to 1.46% DM. The lowest pH values were found in drum silos (3.23) followed by pit (3.37) and bag silos (4.13). The NH_3-N content of drum silos was lower than that of the other silos. Higher lactic acid production was observed in the drum silos compared to the other silos. Across forage systems, pH, NH_3-N and lactic acid production were 3.07 to 4.57, 2.91 to 16.32% TN and 0.84 to 1.82% DM, respectively. MZ+LB and MZ+CV mixed silages had low pH values and NH_3-N contents, and high lactic acid concentrations compared with sole forage silages. Different silo types and forage systems showed significant effects on pH, NH_3-N, and lactic acid content. The drum silos had significantly lower pH and NH_3-N contents, and high lactic acid production in MZ+LB and MZ+CV mixed silages followed by pit and bag silos.

The acetic, propionic and butyric acid production for different silo types varied from 1.18 to 1.46, 0.14 to 0.60 and 0.55 to 0.93% DM, respectively. The lowest acetic acid concentration was observed in bag silos followed by pit and drum silos. The concentration of propionic acid was highest in the drum silos compared to the other silos. Butyric acid concentration was lowest in the drum silos, followed by pit and bag silos. The acetic, propionic and butyric acid concentrations across forage systems ranged from 0.84 to 1.82, 0.01 to 0.61 and 0.06 to 2.18% of DM, respectively. The acetic, propionic and butyric acid contents were higher in sole maize silages than in mixed silages, and volatile fatty acid concentrations were higher in MZ+CV and MZ+LB mixed silages compared to sole CV and LB forage silages. There were significant ($p \leq 0.05$) differences between the silo types and forage systems in terms of acetic, propionic and butyric acid concentrations. Higher acetic and propionic acid but lower butyric acid contents were observed in drum and pit silos containing sole MZ and mixed silages compared to bag silos.

4. Discussion

4.1. Nutrient composition

Despite the low productivity of forage crops in semi-arid regions, silage making is not widely practiced by smallholders. Ensiled forage crops have potential as a source of feed for livestock during the dry season. The use of different silo types might result in distinct silage characteristics of ensiled forage. Therefore, it is important to identify techniques to use for the storage of forage crops during ensiling. It is well known that DM and CP are important indicators reflecting the quality characteristics of silage (Zhu *et al*., 2022). In this study, silage mixtures had higher DM content compared with sole forage silages. Soe Htet *et al*. (2021) also noted differences in DM content between sole forage silage and silage mixtures. Drum silages had higher DM than that of pit and bag silos. It is plausible that drum silos restricted aeration more than the other silos, allowing for more anaerobic fermentation which limited silage decomposition and microbial activity. Chavan *et al.* (2022) also reported higher DM content in silage stored in plastic drums compared to other storage silos.

Generally, CP includes true protein and non-protein nitrogen and both can be influenced by the storage method and activity of the protein-degrading microorganisms during the ensiling process (Solati *et al*., 2018). In the present study, silage CP contents were higher in drum silos compared to the other silos. The reason might be the favourable conditions for the fermentation process leading to decreased CP loss. As expected, the highest CP concentration was with sole legume silages (CV and LB) and the legumes also increased CP levels in mixed silages. This agrees with Kizilsimsek *et al*. (2017) who reported high CP levels in ensiled soybean–maize mixtures. In the study, the DM value of CV silage was low while the CP content was higher compared to other ensiled forages. A possible reason could be explained by more leafiness with less structure for the ensiled CV. It has been reported that fermented legumes have more protein due to their abundant leaves (Zong *et al*., 2023).

The contents of NDF and ADF of silages may be affected by the storage conditions during the ensiling process (Li *et al*., 2021). In this study, drum silages were characterised by lower NDF and ADF compared to the other silos. In general, mixed crop silages were lower in NDF and higher in ADF content than sole forage legumes. Similarly, Aloba *et al*. (2022) ensiled tropical legumes with sorghum, also reported that storage decreased NDF concentration and increased ADF content in silage mixtures.

High-quality silages have low concentrations of NDF and high IVDMD, WSC, and TFA concentrations (Ni *et al*., 2018). In this study, mixed silages had higher IVDMD, WSC and TFA concentrations compared with sole forage silages. Parra *et al*. (2019) reported similar results after ensiling maize with soybean; and Fischer *et al*. (2020) after ensiling maize with different climbing beans. Furthermore, it was found that mixed crop silages in drum silos had high IVDMD, WSC and TFA than the other silos. This can be explained by restricted aeration in drum silos and during the ensiling process. Muck *et al*. (2015) also reported that fermentation was more effective in oxygen-limited silo, which resulted in better preservation of forage chemical constituents.

4.2. Microbial population

Microbial community (LAB, ENT and YM) plays an important role in ensiling process and improves the quality of silage (Zheng *et al*., 2017). In this study, LAB formation was greater in the mixed silages than sole silages, ENT and YM counts tended to be higher in the sole silages than mixed silages. It is likely that high water soluble carbohydrates produced in mixed silages supported in high LAB populations. La Guardia Nave and Corbin (2018) reported a similar effect when ensiling maize with forage legumes and grasses. Silo types had no significant effect on LAB, ENT and differ in YM populations. However, drum silos were higher in LAB and lower in ENT and YM counts than pit and bag silos. The smaller enterobacterial, yeast and mould populations in forage materials ensiled in drum silos could be due to well-preserved silage associated with high lactic acid bacteria and low pH values. Similar results were reported by Du *et al*. (2021) after exploring microbial community structure during silage fermentation.

4.3. Fermentation products

Lower pH, decreased NH_3-N and greater lactic acid concentration in silage indicates good fermentation and quality of ensiled forage (Zhao *et al*., 2021). In the current study, the drum silo had the lowest pH and low NH_3-N content, but highest lactic acid compared with pit and bag silos. High production of lactic acid bacteria produced in drum silos might have facilitated the release of lactic acid, lowered the pH values and NH_3-N concentration. These results are in agreement with those reported by Simard and Lambert-Beaudet (2016) for maize forage ensiled in mini-silos. Moreover, pH tended to be lower in the silage mixtures than sole silages, NH_3-N production was lower in the mixtures than sole silages and lactic acid production was greater in the mixtures than sole silages. Similarly, Xu *et al*. (2022) reported better silage preservation (as evidenced by higher lactic acid and lower pH and NH_3-N concentrations) when ensiling a mixture of maize and alfalfa.

Low pH and organic acids (acetic acid, propionic acid and butyric acid) support preservation of forages crops. Organic acids possess antifungal activity which reduces the spoilage microorganisms and improve fermentation (Guimarães *et al*., 2018). In the present study, the concentration of acetic and propionic acid was higher (and that of butyric acid lower) in drum silos than other silo types. A possible reason for higher concentration of acetic and propionic acid levels in drum silos could be more rapid inhibition of spoilage microorganisms during the fermentation process relative to the other silos. These results are similar to those reported by Zhang *et al*. (2017), who ensiled maize mixed with alfalfa. That sole maize silage produced higher levels of VFAs is in agreement with Baghdadi *et al*. (2016) who reported that VFA concentrations tended to be lower in mixtures than in sole maize silage when using different crop combination ratios.

Silo types showed improved chemical composition, microbial community and fermentation quality in the following order: drum silos > pit silos > bag silos. High crude protein content, increased LAB count, Lower pH values and greater lactic acid concentration in drum silos indicates good fermentation and quality of ensiled forage as per standards reported in good silages. Additionally, mixed silages preserved in the pit and bag silos fermented well with higher *in vitro* dry matter digestibility, lower populations of enterobacteria, higher acetic and propionic acid production. These are properties of good silage for animal feed production. These results are in agreement with those reported by Solórzano *et al*. (2020) for forage silage when ensiled in three different types of mini-silos.

5. Conclusions

Forage yield and nutritive value of silage mixtures were more than that of sole forage silages. In addition, silage chemical composition was enhanced in the drum silos compared to pit and bag silos. These data demonstrate that maize can be intercropped with tropical forage legumes and ensiled to give high quality silage for ruminant animal feeding. All silage mixtures fermented well with higher LAB, smaller enterobacterial populations and low mould and yeast than sole silages. Silage made from bag silos also had lower LAB, greater enterobacterial population and high mould and yeast compared to pit and drum silos. The data demonstrated that drum silos can create an anaerobic environment that eliminates spoilage of ensiled materials from the growth of yeasts, moulds and adverse bacteria. When silage was stored in different silos, the pH and NH_3-N values of the drum silos were the lowest, while lactic, acetic and propionic acids were higher than for pit and bag silos. Moreover, a similar trend was also noted in mixed forage silages. Silage mixtures also had the lowest pH values and NH_3-N contents, low butyric acid and high lactic, acetic, and propionic acid concentrations compared to sole silages. The results indicated that silage mixtures improved forage quality in comparison to the sole crop silages possibly due to the balance of carbohydrates and protein concentrations. The data showed that drum silos can be used as an effective way for preserving feed with minimum nutrient loss. Additional research is required to evaluate the performance of animals fed these silages produced in small scale silos.

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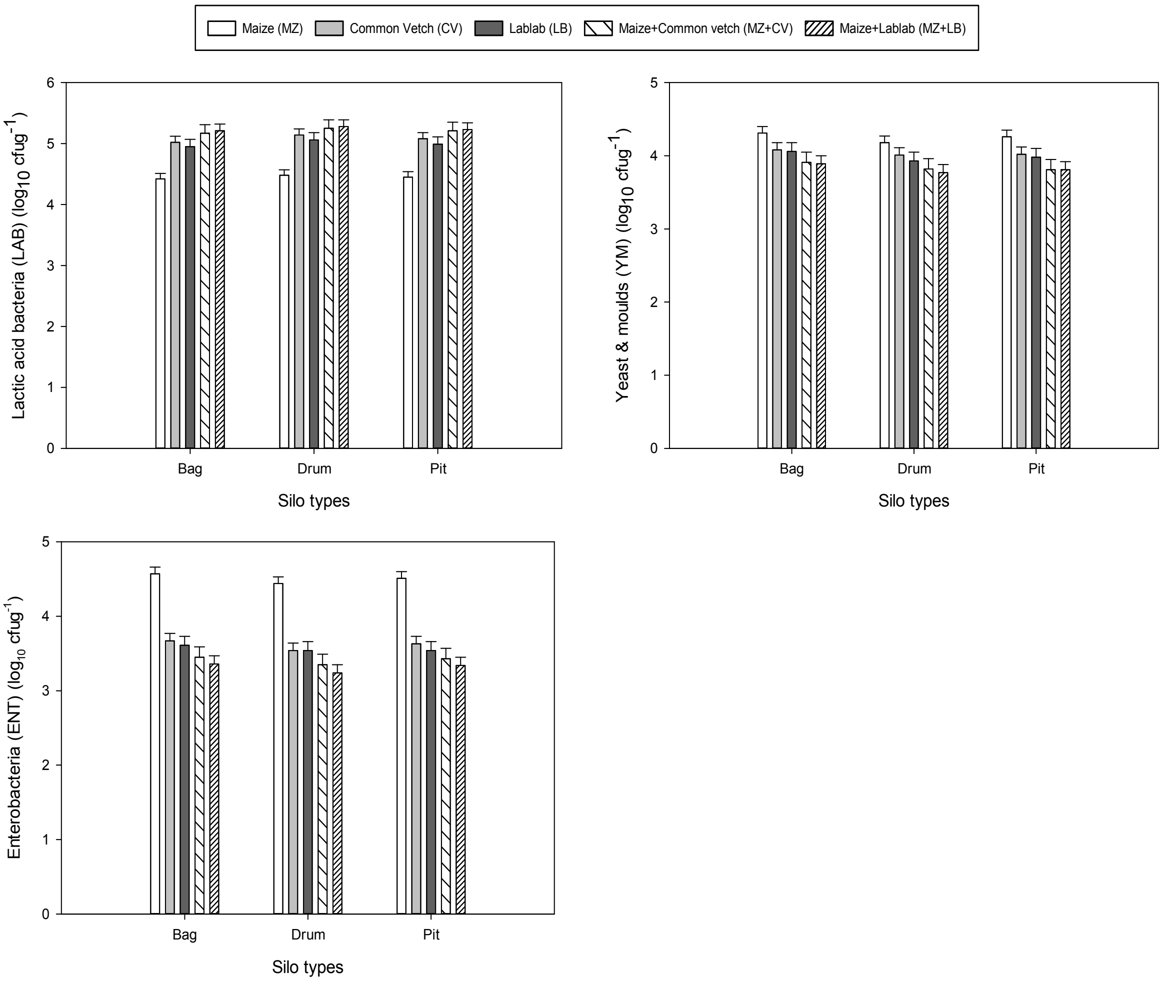

Figure 1: Influence of different silos on the microbial composition [log$_{10}$ cfug^{-1}] of maize and forage legume silages

Three ways of silos are plastic bag, plastic drum and pit silos.
Error bar represents standard error of mean (SEM).

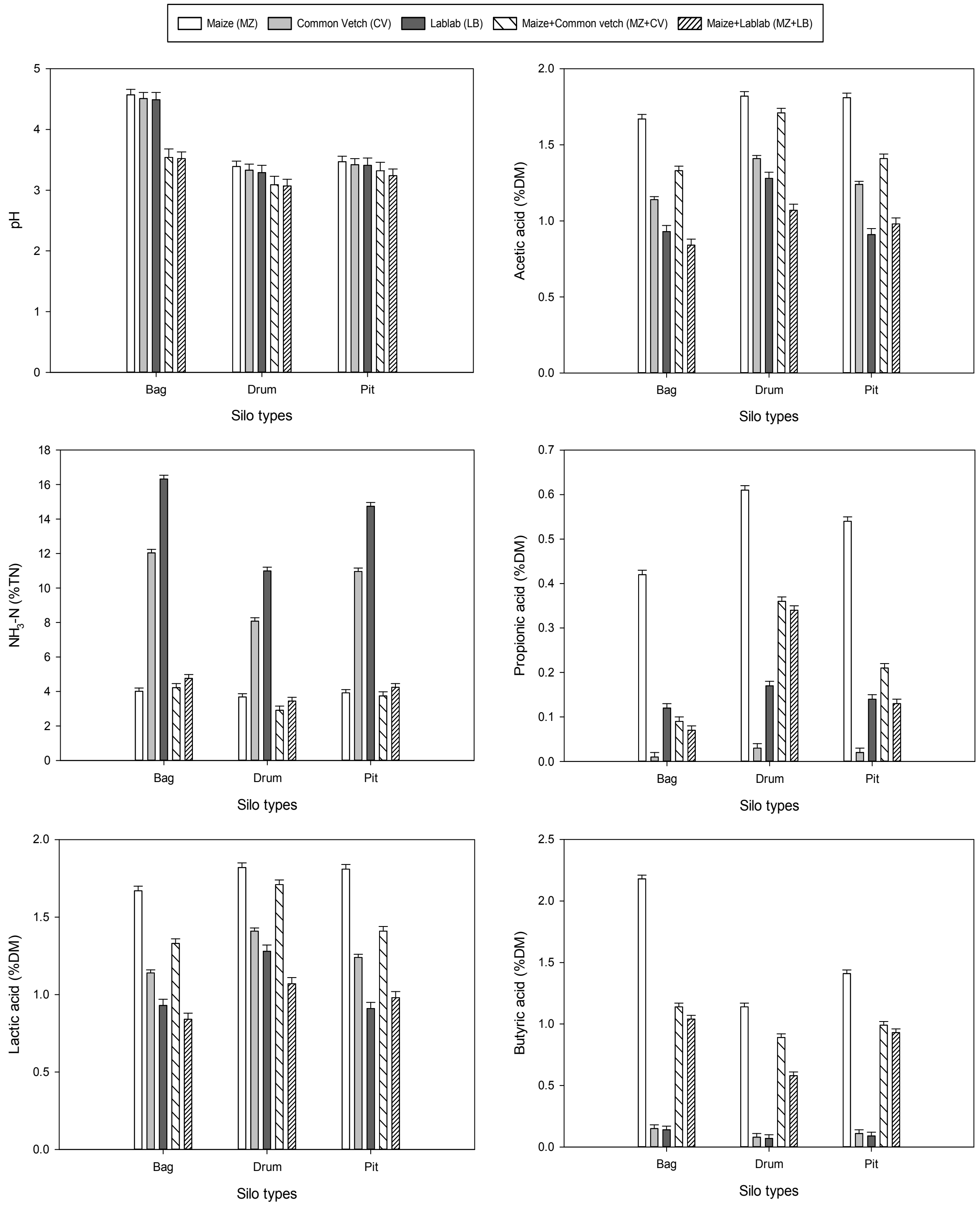

Figure 2: Influence of different silos on fermentation products [% DM and % TN] of maize and forage legume silages

Three ways of silos are plastic bag, plastic drum and pit silos.
Error bar represents standard error of mean (SEM).

Table 1: Chemical composition [%] of maize and legume forages before ensiling

Forage systems^{A}	**DM^{B}**	**CP**	**NDF**	**ADF**	**IVDMD**	**WSC**	**TFA**
				(%)			
MZ	27.17^{c}	6.12^{d}	42.97^{b}	42.31^{b}	55.07^{c}	11.44^{a}	3.70^{a}
CV	17.86^{e}	23.69^{a}	36.29^{c}	28.29^{d}	55.38^{c}	7.36^{b}	1.24^{b}
LB	21.58^{d}	18.11^{b}	45.47^{a}	32.04^{c}	56.48^{bc}	8.39^{b}	1.43^{b}
MZ+CV	34.85^{b}	7.68^{cd}	31.03^{e}	46.53^{a}	58.18^{ab}	12.12^{a}	3.78^{a}
MZ+LB	37.61^{a}	8.11^{c}	33.87^{d}	47.60^{a}	59.57^{a}	11.44^{a}	4.94^{a}
SEM$^{\mathbf{C}}$ (±)	0.34	0.15	0.38	0.45	0.56	0.29	0.11

$^{a\text{-}e}$ Values with different letters within the same column are significantly different (*P* ≤0.05).

^{A} Five forage systems are Maize (MZ), Common vetch (CV), Lablab (LB), Maize+Common vetch (MZ+CV), and Maize+Lablab (MZ+LB).

^{B} Means of three samples for all constituents analysed; DM: Dry matter, CP: Crude protein, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, IVDMD: In vitro dry matter digestibility, WSC: water soluble carbohydrates and TFA: total fatty acid.

^{C} SEM: Standard error of mean.

Table 2: Influence of different silos on the chemical composition [%] of maize and forage legume silages

Forage systems^{1}	**Silos^{2}**	**DM^{3}**	**CP**	**NDF**	**ADF**	**IVDMD**	**WSC**	**TFA**
					(%)			
MZ	Bag	24.74^{g}	6.59^{n}	44.73^{a}	40.34^{b}	43.93^{m}	10.15^{g}	3.69^{f}
	Drum	30.51^{e}	7.24^{l}	32.75^{d}	27.03^{g}	54.35^{i}	11.14^{de}	4.56^{d}
	Pit	26.37^{f}	7.14^{l}	38.43^{c}	35.32^{e}	52.01^{l}	10.51^{f}	4.22^{e}
CV	Bag	15.61^{l}	22.18^{b}	32.67^{d}	24.28^{j}	53.12^{k}	6.26^{l}	1.71^{j}
	Drum	17.26^{k}	23.38^{a}	30.91^{ef}	16.41^{m}	54.66^{h}	7.07^{j}	2.35^{h}
	Pit	17.06^{k}	23.29^{a}	31.75^{de}	21.31^{l}	54.33^{i}	6.63^{k}	2.11^{i}
LB	Bag	18.96^{j}	16.91^{e}	41.87^{b}	26.31^{h}	54.03^{j}	7.28^{j}	1.99^{i}
	Drum	21.37^{h}	17.76^{c}	38.41^{c}	23.82^{k}	55.76^{g}	8.11^{h}	2.54^{g}
	Pit	20.78^{i}	17.62^{d}	40.93^{b}	25.05^{i}	55.58^{g}	7.71^{i}	2.28^{h}
MZ+CV	Bag	33.05^{d}	8.43^{k}	27.26^{i}	41.81^{a}	56.38^{f}	11.01^{e}	4.24^{e}
	Drum	34.25^{c}	8.86^{i}	25.76^{j}	34.87^{f}	57.45^{c}	11.82^{c}	4.85^{c}
	Pit	34.05^{c}	8.58^{j}	26.49^{ij}	39.54^{c}	57.24^{d}	11.26^{d}	4.65^{d}
MZ+LB	Bag	35.15^{b}	9.03^{h}	30.01^{fg}	42.03^{a}	56.68^{e}	11.31^{d}	4.67^{d}
	Drum	37.12^{a}	9.46^{f}	28.49^{h}	38.63^{d}	58.84^{a}	12.55^{a}	5.87^{a}
	Pit	36.79^{b}	9.25^{g}	29.32^{gh}	40.61^{b}	58.27^{b}	12.14^{b}	5.52^{b}
SEM$^{\mathbf{4}}$ (±)		1.15	0.92	0.89	1.26	0.52	0.11	0.23

$^{a\text{-}m}$ Values with different letters within the same column are significantly different (*P* ≤0.05).

[1] Five forage systems are Maize (MZ), Common vetch (CV), Lablab (LB), Maize+Common vetch (MZ+CV), and Maize+Lablab (MZ+LB).

[2] Three ways of silos are plastic bag, plastic drum and pit silos.

[3] DM: Dry matter, CP: Crude protein, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, IVDMD: In vitro dry matter digestibility, WSC: water soluble carbohydrates and TFA: Total fatty acid.

[4] SEM: Standard error of mean.

ABSTRACT

This study was conducted to evaluate the ensiling characteristics of maize-forage legume mixtures in small-scale silos. Sole and intercrops forage materials were harvested 80 days after planting and ensiled in small-scale silos, *viz*. plastic bags, plastic drums, and small pits for 60 days. After ensiling, samples were collected to examine the chemical composition, microbial community, and fermentation quality. Mixed silages stored in the drum silos had significantly ($p \leq 0.05$) higher DM content (35.69%) than that from pit and bag silos. The drum silos had significantly ($p \leq 0.05$) higher crude protein concentration (20.57% DM) in sole legume silages than other silo types. Neutral detergent fibre concentration (39.76% DM) of sole forage silages was greatest in bag silos than in other silos. High *in vitro* dry matter digestibility and water-soluble carbohydrate values (58.15 and 12.19% DM respectively) for mixed silages were recorded in drum silos. Bag silos showed lower numbers of lactic acid bacteria and higher populations of enterobacteria (4.86 and 4.26 $\log_{10}$ CFUg^{-1} respectively) in sole forage silages than other silos. Mixed silages ensiled in drum silos produced significantly lower ($p \leq 0.05$) pH (3.03) and ammonia nitrogen content (3.73%TN) compared to pit and bag silos. The study concluded that ensiling maize-forage legume mixtures in drum silos can have a positive effect on the nutritive value of ruminants' feeds. Therefore, the recommended forage type for ensiling is mixed silages.

Keywords: Mixed crop silage; forage composition; microbial population; fermentation profile