Revista Brasileira de Zootecnia
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ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., 45(10):596-603, 2016

Effects of ensiling density on nutritive value of maize and sorghum silages

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ABSTRACT - Studies were conducted to determine the effects of different ensiling densities on fermentation, aerobic stability, and nutritive value of maize and sorghum silages. Maize and sorghum were harvested at dough (363 g/kg) and milk stages (275 g/kg), respectively. Herbages were chopped approximately 1.5 cm after harvest and then ensiled in mini silos at high and low-bulk densities for 8.5 weeks. Different bulk densities were achieved by ensiling different weights of herbage in the fixed-volume mini silos (1.5-L anaerobic jars, Weck, Germany). The obtained dry matter (DM) densities were 168 and 216 kg of DM/m^3 for maize forage and 132 and 178 kg of DM/m^3 for sorghum forage. Fermentation kinetics, the rate of aerobic deterioration upon aerobic exposure, and nutrient digestibility were followed during the periods of ensiling (on days 2, 4, 8, 15, and 60). In all cases, increased packing density resulted in silages with lower acetate content, ammonium N levels, and fermentation losses, but lactate content did not differ. Butyrate was detected in appreciable amounts only in sorghum silage. Propionate was not detected in any silage. Tightly packed silages remained stable upon exposure to air. Tight packing increases the digestibly of nutrients and improves the energy content of silages. These data show that high density limits air infiltration and reduces the oxidation loss during storage and feed-out. As a consequence, more dry matter is recovered and more energy is preserved.

Key Words: cereals, nutritional profile, packing density, silage

Introduction

In the last decade, the cost of animal production has increased, while the income from milk and meat products have not increased as quickly. This has created the need for animal production to find methods that are more efficient and profitable. One of the most effective methods is producing high-quality forages and using more forage in the diet of animals. Maize and sorghum are the main silages for feeding cattle (Wilkinson and Toivonen, 2003). The most important factor that affects the quality of silage is the ability to pack the silage to control and maintain anaerobic conditions (McDonald et al., 1991). This is achieved by packing silage at a higher density. Packing silage tightly minimizes excessive air, which can result in aerobic respiration and heat (Muck et al., 2004; Savoie et al., 2004). Heat can cause the loss of digestible nutrients and can increase the production of mold spores and mycotoxins (McDonald et al., 1991; Charley, 2008). This was similar to the research of Kung Jr (2010), who stated that lower packing density slowed down ensiling fermentation and aided the level of yeasts produced in the silage, which were found upon opening. It has been suggested that air infusion during storage and feed-out in commercial scale maize silage can contribute to clostridial growth in the peripheral areas of the silo (Borreani and Tabacco, 2009). Ruppel et al. (1995) found that the packing density negatively affected storage losses. Their findings included using a model for a six-month period and they found that losses decreased from 20 to 10% when packing was increased from 160 to 320 kg DM/m^3. Another important factor affected by density is the maintenance and preservation of nutrients between the time of opening the silo and the time of using the silage as feed (Johnson et al., 2002; Wilkinson and Davies, 2013). Deteriorated silages cause a serious risk to the quality and safety of animal products and to animal health (Driehuis and Oude Elferink, 2000).

Under our conditions within the Mediterranean climate, two effects would be of greatest interest: a reduction of in-silo losses by an optimized fermentation process and a reduction of losses after the opening of the silo by improving the aerobic stability. Both types of losses are closely correlated to the concentration of oxygen present in the silo, which promotes unwanted microbes. There is little published information about the initial packing density effects on silage quality. Therefore, the objective of this

Received May 20, 2016 and accepted August 1, 2016.
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http://dx.doi.org/10.1590/S1806-92902016001000003

study was to investigate the effects of different ensiling densities on fermentation, aerobic stability, and nutritive value of maize and sorghum silages.

Material and Methods

Silages were prepared from maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L.) and grown in the same years at the Agricultural Experimental Station (40°14' N, 28°50' E). Whole-crop maize and sorghum were cut at the dough (363 g/kg) and milk stages (275 g/kg), respectively. The forages were chopped (1.5 cm) with a laboratory chopper (Fimaks, Turkey). Three representative samples of fresh chopped forages were collected and frozen for subsequent analysis. Different bulk densities were achieved by ensiling different weight of herbage in the fixed-volume mini silos (1.5-L anaerobic jars, Weck, Germany). To achieve two different bulk densities for maize forage, jars were filled with 1050 and 1350 g (wet weight) of chopped maize, without a headspace. The obtained dry matter (DM) densities were 168 and 216 kg of DM/m^3 for maize forage. To achieve two different bulk densities for sorghum forage, jars were filled with 1100 and 1450 g (wet weight) of chopped sorghum, without a headspace. The obtained DM densities were 132 and 178 kg of DM/m^3 for sorghum forage. The openings of the mini silos were performed in a five-day temporal series on days 2, 4, 8, 15, and 60 after filling. There were 60 jars (two forages × five days × two ensiling density × three parallels) and they were stored at an ambient temperature of 25-28 °C. Ensiled forages (on days after ensiling, three jars per treatment for each time) were sampled for further analysis.

Chemical analyses of fresh forage and silages were performed in triplicate and presented on DM basis. The silage pH was measured directly from the silage juice using a pH meter (Sartorius PB-20, Germany). Fresh forages and silage samples were dried at 60 °C for DM determination (AOAC, 1990). Dry matter content of the silages was corrected (DM_{cor}) for the loss of volatile substances during drying through the following equation (Weißbach, 2009): DM_{cor} = DM + 0.95 × sum of fatty acids (C2-C6) + 0.08 × lactic acid + 0.77 × 1,2 propanediol + 1.00 × other alcohols (C2-C6 including butanediol) [g/kg]. Fresh forage and silages were analyzed for crude protein (CP) and ash according to AOAC (1990). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the sequential analysis scheme of Van Soest et al. (1991). Wet samples stored at –20 °C were extracted for 3 min in a blender in water or in ethyl acetate (1:9) for water-soluble carbohydrates (WSC) and analysis of fermentation products. The WSC were determined as described by Dubois et al. (1956). Lactic acid was determined by the procedures of Barker and Summerson (1941). The volatile fatty acids (VFA) and alcohol concentrations were analyzed using a gas chromatograph with a capillary column (over a temperature range of 45-230 °C). Ammonia-N was determined using a Kjeltech auto analyzer (Gerhardt, Germany). Microbiological analyses of fresh forage and silages were presented on fresh and wet silage basis. Microbiological evaluation included enumeration of *lactobacilli* on pour-plate rogosa agar (Oxoid CM627, Oxoid, Basingstoke, U.K.) and yeast and mold on spread-plate malt extract agar (Difco, Detroit, MI), acidified with lactic acid to pH 4.0. Plates were incubated for 3 d at 30 °C. All microbiological data were transformed into $\log_{10}$.

At the end of the ensiling period (d 60), the silages were subjected to an aerobic stability test at room temperature (22 °C), which lasted 5 d, in a "polyethylene terephthalate (P.E.T.) bottle" system developed by Ashbell et al. (1991). The system was constructed from recycled soft drink bottles (polyethylene terephthalate) in two parts: the upper part (1-L) was filled with 250 g (wet weight) of loosely packed silage and the lower part with 100 mL of 20% KOH. Gas was exchanged through 1-cm holes in the lid of the upper part to the lower part. The CO_2 produced during aerobic exposure was absorbed in the base and determined by titration with 1 N HCl. In addition, silage pH was measured and yeast and mold analyses were performed as the indicators of aerobic spoilage as well. The pH and yeast and mold analyses were determined by the previously explained analysis methods. Analyses were carried out in the silage samples after 5 d of exposure to air.

In vitro digestible DM (dDM) and digestible neutral detergent fiber (dNDF) were determined according to Holden (1999) for each silage using a DaisyII Incubator (Ankom® Technology Corp., Fairport, NY, USA) and a fiber analyzer (ANKOM Technology Corporation).

Digestible organic matter (dOM) and metabolizable energy (ME) values in silages were calculated from the following equation (Menke and Steingass, 1988): dOM, (%) = 0.9042 × GP + 0.0492 × CP + 0.0387 × CA + 16.49 and ME, MJ kg DM = 2.20 + GP × 0.14 + CP × 0.006 + EE2 × 0.0003, in which GP is the amount of net gas production at 24 h (0.2 g DM) and CP, CA, and EE are crude protein, crude ash, and ether extract (% DM), respectively.

The data obtained from silage quality were analyzed as a completely randomized design with three replications and subjected to analysis of variance by the GLM procedure of SAS (Statistical Analysis System, version 6.0). Differences among means were tested using Tukey's test and significance was declared at $P<0.05$.

Results

The fresh maize had 363 g DM/kg with a pH value of 5.92 (Table 1). The NDF and ADF contents of fresh maize were 542 and 333 g/kg DM, respectively. Pre-ensiled maize had adequate levels of WSC (66 g/kg DM), but was relatively low in protein content (70 g/kg DM). The fresh sorghum had 270 g DM/kg with a pH value of 6.05. The NDF and ADF contents of fresh sorghum were 578 and 360 g/kg DM, respectively. Pre-ensiled sorghum had high levels of WSC (33 g/kg DM), but contained low levels of protein (51 g/kg DM). The epiphytic *lactobacilli* and yeast counts were high in both herbages, each being 10-log cfu/g.

Both ensiling density and the day of fermentation affected (P<0.05) the chemical composition of silages (Table 2). These effects were stronger (P<0.05) at the initial stage of fermentation. The DM recovery was higher (P = 0.06) in tightly packed silages than in loosely packed silages. Loosely packed sorghum silages had higher (P<0.05) fermentation losses than maize silages. The fiber fractions and protein content of silages were unaffected (P>0.05) by the packing density.

Maize and sorghum silages appeared to have fermented normally, as indicated by the final pH levels of 3.8 and 3.6 and fermentation acid levels of 83 to 72 g/kg DM, respectively (Table 3). Both ensiling density and the day of fermentation exerted a substantial influence on the fermentation profile of silages (P<0.05). Thus, the difference between the higher packing densities was much greater for initial stages of fermentation than the latter stages of fermentation for both types of silages (P<0.05). Within the first week of fermentation, nearly 80% of the total carbohydrates available were metabolized in maize and sorghum silages (P<0.05). As fermentation progressed, the concentration of lactic acid increased and the concentration of acetic acid decreased (P<0.05). Overall, the level of packing density did not influence (P>0.05) the lactate production, but influenced the acetate and ammonium-N levels (P<0.05). Lower levels were obtained in tightly packed silages (P<0.05). The accumulation of butyric acid was not seen in maize silages. However, a very small amount was seen in sorghum silages and were lower in tightly packed silages (P<0.05). The concentrations of alcohols were decreased with the fermentation progress and lower levels were obtained in tightly packed silages (P<0.05).

Table 1 - Chemical composition and epiphytic *lactobacilli* of pre-ensiled maize and sorghum

	Maize	Sorghum
Dry matter (g/kg)	363.3±2.22	275.1±1.32
DM_{cor}	370.9±1.60	276.4±5.46
pH	5.92±0.11	6.05±0.13
Crude protein (g/kg DM)	73.4±1.65	50.6±3.11
Ash (g/kg DM)	53.8±0.99	50.0±0.69
Neutral detergent fiber (g/kg DM)	577.6±20.05	642.1±40.7
Acid detergent fiber (g/kg DM)	332.6±9.32	359.3±60.3
Hemicellulose[1] (g/kg DM)	245±24.12	282.2±46.1
Water soluble carbohydrates (g/kg DM)	66.0±3.8	32.6±3.41
Lactate	15.28±0.96	9.97±0.74
Acetate	6.67±0.21	0.39±0.32
Butyrate	0	0.03±0.04
Alcohols	0	0.12±0.06
NH_3-N (g/kg TN)	5.33±0.61	4.22±0.22
Lactobacilli (log cfu/g DM)	9.71	10.0
Yeast	10	9.65

DM - dry matter; DM_{cor} - dry matter corrected for loss of volatiles; NDF - neutral detergent fiber; ADF - acid detergent fiber; NH_3-N - ammonium nitrogen; TN - total nitrogen; cfu - colony-forming units.
[1] Hemicellulose calculated as the difference between NDF and ADF.

Two weeks after the beginning of fermentation, the amount of *lactobacilli* was higher than after eight weeks of fermentation (Table 4). The yeast count after two weeks was higher, but at eight weeks it was negligible. The total number of yeasts was 50% higher in the loosely packed silages than in the tightly packed. The yeast counts were higher in the sorghum silages than in the maize silage. No mold growth was detected.

The pH and CO_2 production within five days of air exposure was higher (P<0.05) in loosely packed silages than in tightly packed silages (Table 5). The most significant improvement in aerobic stability was seen in the silages with the highest packing density because of the lower yeast activity (P<0.05). Loosely packed sorghum silages had higher CO_2 production and yeast counts than maize silages. Regardless of the packing rate, no mold growth was observed in the silages. Visible molds were low in both types of silages that were exposed to air, each being one.

The level of packing density affected (P<0.05) the content of digestible DM, NDF, and OM and the calculated ME content of silages (Table 6). These parameters were higher in the tightly packed vs. the loosely packed silages (P<0.05). Tightly packed maize silage had 21% higher OM digestibility and 31.5% higher energy content than sorghum silages.

Discussion

One of the most important factors influencing preservation characteristics and nutritive value of forages is the density of forage mass and the levels of air-filled porosity in the silo (McDonald et al., 1991). Thus, the ensiling density is important in the influence on the fermentation course and final fermentation quality as well as animal performance.

In this study, factors affecting the pattern of fermentation in the silo are considered and the effects

Table 2 - Chemical composition of maize and sorghum silages (g/kg DM) at two ensiling densities

Item	DM	DM_{cor}	Losses %	CP	Ash	NDF	ADF	HC
				Maize silage				
Day (D)								
2	364.50	389.85	1.40a	76.00a	52.05	572.50	297.25	275.25
4	370.15	391.20	1.46a	74.05b	51.00	619.40	281.25	338.15
8	368.95	388.85	1.44a	73.00c	51.90	623.70	324.15	299.55
15	368.80	388.10	1.43a	72.15d	53.60	571.45	286.75	284.70
60	373.25	393.85	1.11b	75.65ab	54.50	530.35	266.65	263.70
SEM	60.00	61.00	0.15	27.00	2.1	22.50	13.80	27.60
P-value	0.12	0.16	0.20	<0.01	0.46	0.53	0.12	0.18
Ensiling density (ED)								
Low	366.70	389.56	1.53a	74.28	55.00	596.02	299.64	296.38
High	371.56	391.18	1.20b	74.06	51.42	570.94	282.78	288.16
SEM	55.00	55.30	0.17	30.00	2.3	25.10	15.50	30.90
P-value	0.06	0.07	<0.01	0.20	0.58	0.42	0.14	0.25
D × ED								
2 Low	365.30	392.40	1.64a	79.20a	50.60	604.30	290.20	314.10
High	363.70	387.30	1.15c	72.80c	53.50	540.70	304.30	236.40
4 Low	367.40	391.60	1.54a	72.80c	49.30	622.10	285.70	336.40
High	372.90	390.80	1.38a	75.30bc	52.70	616.70	276.80	339.90
8 Low	365.30	387.00	1.59a	72.90cd	52.40	623.10	317.70	305.40
High	372.60	390.70	1.29b	73.10d	51.40	624.30	330.60	293.70
15 Low	363.50	383.70	1.60a	70.40e	51.00	597.70	317.70	280.00
High	374.10	392.50	1.26c	73.90d	46.20	545.20	255.80	289.40
60 Low	372.00	393.10	1.27c	76.10b	51.70	532.90	286.90	246.00
High	374.50	394.60	0.94e	75.20bc	53.30	527.80	246.40	281.40
SEM	58.00	58.10	0.16d	24.00	3.2	23.80	14.70	29.25
P-value	0.08	0.09	<0.01	<0.01	0.55	0.54	0.23	0.19
				Sorghum silage				
Day (D)								
2	276.65	292.75	3.22a	57.20	53.95	664.95	393.25	271.70
4	276.60	285.35	3.62a	58.10	51.80	674.20	395.85	278.35
8	277.55	286.00	3.08a	54.85	52.70	644.25	377.65	266.60
15	277.00	298.85	3.42a	53.50	55.35	660.10	410.95	249.15
60	278.70	290.80	2.90ab	59.45	57.45	658.00	346.80	311.20
SEM	65.20	66.00	0.19b	2.7	2.0	16.70	24.30	20.20
P-value	0.61	0.52	<0.01	0.16	0.68	0.64	0.48	0.82
Ensiling density (ED)								
Low	275.56	286.86	5.03a	59.78	54.28	666.46	370.96	295.50
High	279.04	294.64	1.46b	53.46	54.22	654.14	398.84	255.30
SEM	60.60	52.00	0.21	3.0	2.3	18.70	27.20	22.60
P-value	0.44	0.39	<0.01	0.20	0.65	0.20	0.36	0.77
D × ED								
2 Low	274.40	290.90	5.65a	57.40	53.60	665.70	395.60	270.10
High	278.90	294.60	0.79d	57.00	54.30	664.20	390.90	273.30
4 Low	275.90	276.70	5.59a	55.30	52.00	678.50	394.30	284.20
High	277.30	294.00	1.64	50.90	51.60	669.90	397.40	272.50
8 Low	275.20	291.40	4.53b	53.80	51.90	659.90	371.80	288.10
High	279.90	280.60	1.62c	55.90	53.50	628.60	383.50	245.10
15 Low	275.80	297.80	5.32a	57.50	56.70	661.60	389.80	271.80
High	278.20	299.90	1.52c	49.50	54.00	658.60	432.10	226.50
60 Low	276.50	277.50	4.05b	54.90	57.20	666.60	303.30	363.30
High	280.90	304.10	1.74c	54.00	57.70	649.40	390.30	259.10
SEM	63.40	59.00	0.20	2.9	2.1	17.70	26.10	21.30
P-value	0.53	0.44	<0.01	0.07	0.60	0.58	0.65	0.49

DM - dry matter; DM_{cor} - dry matter corrected for loss of volatiles; CP - crude protein; NDF - neutral detergent fiber; ADF - acid detergent fiber; HC - hemicellulose calculated as the difference between NDF and ADF; SEM - standard error of the mean.
Means in the same column with different letters differ significantly (P<0.05).

Table 3 - Fermentation metabolites of maize and sorghum silages (g/kg DM) at two ensiling densities

Item	pH	WSC	Lactate	Acetate	Butyrate	Alcohols	NH_3-N g/kg TN
			Maize silage				
Day (D)							
2	4.31a	54.50d	33.22cd	23.67a	ND	0.22a	7.04d
4	4.04b	220.00a	32.63d	19.20b	ND	0.25a	7.56bc
8	3.83c	162.00b	35.42c	17.83bc	ND	0.17b	7.26cd
15	3.82c	153.50bc	47.41b	16.16cd	ND	0.15b	8.65a
60	3.74d	169.00b	67.03a	15.91d	ND	0.12c	7.86b
SEM	0.30	36.00	2.94	2.26	-	0.03	0.12
P-value	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01
Ensiling density (ED)							
Low	3.96a	128.00b	42.66	20.28a	ND	0.19a	8.36a
High	3.93b	175.60a	43.62	16.82b	ND	0.17b	6.99b
SEM	0.40	32.00	3.29	2.53	-	0.04	0.07
P-value	<0.01	<0.01	0.34	<0.01	-	<0.01	<0.01
D × ED							
2 Low	4.35a	41.0g	32.46cd	25.53a	ND	0.23b	7.81d
High	4.27a	68.0f	33.98cd	21.81c	ND	0.20b	6.27f
4 Low	4.05b	175.0bc	32.42cd	22.56b	ND	0.22b	8.09cd
High	4.02b	265.0a	32.83cd	15.83f	ND	0.28a	7.02e
8 Low	3.79d	162.0c	34.30c	19.77d	ND	0.21b	8.36bc
High	3.87c	162.0c	36.53c	15.88f	ND	0.12d	6.15f
15 Low	3.85c	106.0e	47.22b	17.08e	ND	0.17c	8.64ab
High	3.79d	201.0ab	47.60b	15.23f	ND	0.13d	8.67ab
60 Low	3.75d	156.0cd	66.91a	16.48ef	ND	0.12d	8.91a
High	3.72e	182.0b	67.15a	15.34f	ND	0.11d	6.82e
SEM	0.40	34.00	3.00	2.40	-	0.04	0.16
P-value	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01
			Sorghum silage				
Day (D)							
2	4.30a	64.70e	23.14d	13.72cd	0.96a	0.31e	5.54a
4	4.03b	137.00a	27.39c	14.36c	0.16e	0.46d	5.60a
8	3.83c	127.80ab	31.54bc	19.39ab	0.25d	0.67c	6.06b
15	3.74d	103.05c	34.33b	20.08a	0.30c	0.84b	5.38a
60	3.63e	89.00d	48.23a	21.92a	0.45b	1.36a	5.04b
SEM	0.50	10.20	3.10	1.88	0.07	0.02	0.08
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ensiling density (ED)							
Low	3.92a	91.90b	31.90	18.23	0.47a	0.76a	5.43a
High	3.89b	116.72a	33.95	17.56	0.37b	0.70b	5.23b
SEM	0.60	11.40	3.48	2.09	0.08	0.02	0.05
D × ED	<0.01	<0.01	0.31	0.35	<0.01	<0.01	<0.01
2 Low	4.35a	63.50e	22.68e	13.99	1.12a	0.33f	5.56ab
High	4.24a	65.90e	23.59e	13.44	0.80b	0.29f	5.52ab
4 Low	4.05b	123.20b	26.00d	14.69	0.17a	0.05e	5.68a
High	4.00b	150.80a	28.78cd	14.03	0.14f	0.43e	5.52ab
8 Low	3.87c	105.70c	31.18c	19.56	0.26e	0.69d	5.07cd
High	3.79d	149.90a	31.89c	19.22	0.23e	0.65d	5.06cd
15 Low	3.73d	98.10d	32.87bc	20.47	0.31d	0.87c	5.50ab
High	3.75d	108.00c	35.79b	19.69	0.28e	0.80c	5.027bc
60 Low	3.60e	69.00e	46.77a	22.42	0.48c	1.40a	5.31bc
High	3.65e	109.00c	49.69a	21.42	0.41c	1.32b	4.78d
SEM	0.60	10.70	3.30	1.98	0.08	0.02	0.11
P-value	<0.01	<0.01	<0.01	0.28	<0.01	<0.01	0.16

WSC - water soluble carbohydrates; ND - not detected; NH_3-N - ammonium nitrogen; TN - total nitrogen; SEM - standard error of the mean.
Means in the same column with different letters differ significantly (P<0.05).

of ensiling density on silage quality are illustrated. As expected, ensiling maize and sorghum benefit the maintenance of silage protein content close to that of the fresh forage. The reduction in ammonia-N of tightly packed silages is indicative of lower proteolytic activity, which may have resulted in improved protein-N utilization in the rumen. This hypothesis for improvement in protein-N utilization of well-preserved silages has been proposed previously. Sharp et al. (1994) investigated the digestion of well-preserved silages with 16-month-old Jersey heifers and reported a 33% improvement in efficiency of microbial protein synthesis. The overall drop in pH values reflected the production of acidic metabolites. The decrease of acetic acid in silages in the later stages of fermentation is the result of the achievement of anaerobic conditions in both types of silages (McDonald et al., 1991). However, the final WSC and the fermentation acid concentrations were, respectively, 89 and 15% higher in the maize silages than in the sorghum silages. These differences can be explained by the maturities (Tabacco et al., 2009). Differences in yeast populations, resulting from aeration (because of the different consolidation rates), become less apparent as the fermentation progressed. Mold that was present on the fresh maize and sorghum was not similarly active on the corresponding silages. These results would suggest that the fermentation pattern was predominantly homolactic (McDonald et al., 1991; Gerlach et al., 2013) and this led to lower fermentation losses, especially in tightly packed silages (Ruppel, 1992; Losand, 2003; Savage et al., 2015).

Table 4 - Microbiological composition of maize and sorghum silages (log cfu/g) at two ensiling densities

Item		*Lactobacilli*	Yeasts
		Maize silage	
Day (D)			
2		11.10	8.65
4		10.95	6.95
8		10.45	6.10
15		9.60	4.50
60		7.65	3.85
Ensiling density (ED)			
Low		9.79	6.06
High		10.10	5.96
D × ED			
2	Low	11.00	8.40
	High	11.20	8.88
4	Low	10.70	7.19
	High	11.20	6.74
8	Low	10.50	6.00
	High	10.40	6.18
15	Low	9.45	4.65
	High	9.74	4.30
60	Low	7.30	4.00
	High	7.98	3.70
		Sorghum silage	
Days (D)			
2		10.82	9.27
4		10.60	6.05
8		10.55	5.20
15		10.30	5.15
60		8.40	4.95
Ensiling density (ED)			
Low		9.97	6.44
High		10.31	5.82
D × ED			
2	Low	10.74	9.48
	High	10.90	9.06
4	Low	10.54	6.22
	High	10.73	5.85
8	Low	10.51	5.27
	High	10.64	5.08
15	Low	10.11	5.66
	High	10.47	4.60
60	Low	7.95	5.46
	High	8.80	4.40

cfu - colony-forming units.
Microbiological analysis was performed on a single sample each time. Therefore, no statistical analyses are available.

Table 5 - Results of aerobic stability test (5 d) for maize and sorghum silages at two ensiling densities after a 60 d storage period

Forage	Ensiling density	pH	CO_2 (g/kg DM)	Yeast (log_{10} cfu/g)	Mold	Visible molding[1]
Maize silage	Low	5.82a	7.79a	8.22	0	1
	High	4.82b	5.89b	6.20	0	1
	SEM	0.02	1.01	-		
Sorghum silage	Low	5.69a	49.90a	10.40	0	1
	High	4.65b	8.57b	9.28	0	1
	SEM	0.03	4.25	-	-	-

DM - dry matter; log - logarithm of the numbers; cfu - colony-forming units; SEM - standard error of the mean.
Microbiological analysis was performed on a single sample each time. Therefore, no statistical analyses are available.
[1]Visual appraisal is expressed using a scale of 1 to 5, in which 1 = good quality silage with no visible molding; 2 = a few small mold spots; 3 = scattered mold spots; 4 = silage with partially covered molds, lumpy silage; 5 = completely mold-covered samples, unpleasant odor, and silage particles sticking together.
Means in the same column with different letters differ significantly (P<0.05).

Table 6 - *In vitro* rumen digestible dry matter, fiber and organic matter, and calculated metabolizable energy values for maize and sorghum silages at two ensiling densities after a 60 d storage period

Forage	Ensiling density	dDM	dNDF	dOM	ME MJ/kg DM
Maize silage	Low	564.3b	385.8b	421.5b	7.01b
	High	598.1a	402.6a	509.5a	8.39a
	SEM	1.76	1.14	1.62	0.25
Sorghum silage	Low	539.0b	364.7b	374.7b	5.64.0b
	High	598.5a	404.9a	422.0a	6.38.0a
	SEM	2.50	1.26	3.49	0.53

dDM - digestible dry matter; dNDF - digestible neutral detergent fiber; dOM - digestible organic matter; ME - metabolizable energy; DM - dry matter; SEM - standard error of the mean.
Means in the same column with different letters differ significantly (P<0.05).

Zhang and Yu (2015) evaluated the effects of the two levels of ensiling wet densities (500 and 600 kg/m^3) on the silage quality of *Leymus chinensis* silage. They found that lactic acid content was higher while the pH value, butyric acid, ammonium-N concentration, and the coliform bacteria were lower in high-density silage (600 kg/m^3). Savage et al. (2015) observed that lactic acid concentration was higher in maize silage ensiled at a rate of 240 kg of DM/m^3 dry density (5.55%) than at 170 kg of DM/m^3 density (4.40%). Rota et al. (2012) demonstrated the fermentation quality of maize silage (256 g/kg) when ensiled at a rate of 246 kg DM/m^3 packing dry density for 110 days into 2-L micro silos. They reported that DM losses were 7.12%, lactic acid was 93.9 g/kg DM, acetic acid was 22 g/kg DM, and ethanol was 7.49 g/kg DM.

Test for the aerobic stability based on CO_2 production showed that the presence of air during ensiling due to low packing density gave rise to poor post-storage quality in both silages. The set of deterioration process showed an increased level in pH values above five and a rise in yeast counts by seven log units (Vissers et al., 2007). These numbers were found in loosely packed silages (McDonald et al., 1991). The data from the stability tests reconfirm the findings of Tabacco et al. (2011) that tightly packed silages (612 kg/m^3) is more stable than loosely packed silages (577 kg/m^3). In that study, the spoiled silages also tended to show thermal instability. Further investigations by Windle and Kung Jr (2013) showed that that aerobically spoiled silage-based total mixed ration (TMR) contained 7.8 log cfu yeast/g at the time of feed-out, whereas the fresh TMR contained 5 log cfu yeast/g. Ruppel et al. (1995) and Muck et al. (2003) stated that greater silage density and feed-out rate together increase the time that silage is exposed to air without spoiling before removal from the silo.

The improved fermentation and aerobic stability of both silages may mirror what is observed in animal performance (McDonald et al., 1991; Gerlach et al., 2013; Windle and Kung Jr, 2013). Indeed, we observed that tightly packed silages had higher amount of degradable OM in the rumen and increased the energy content by 21 (maize silage) and 13% (sorghum silage), which indicates a conservation of nutrients (McDonald et al., 1991). Our results are in agreement with Flynn (1988), who demonstrated that in well-preserved and poorly preserved silages for cattle feed, the DM digestibility was 73.5 and 70.7%, respectively. The effects of hygienic quality of silage on DM intake of dairy cows were previously examined (Wichert et al., 1998) and it has been seen that aerobic deterioration led to a decrease in DM intake of about 10-20%. Feeding heifers with spoiled TMR resulted in lower DM intakes when compared with fresh TMR (Windle and Kung Jr, 2013). Aerobic deterioration can jeopardize the nutritive value of maize silage-based diets and can cause a reduction in feed intake of goats by 53% (Gerlach et al., 2013) and steers by 16% (Bolsen et al., 2002).

Conclusions

The more tightly packed silages enables better conservation of soluble carbohydrates, preserves silage proteins, and creates less change of structural carbohydrates. It increases post-storage stability aspects, which favor the acceptability and intake of silage that can enhance the animal performance.

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