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COMPARISON OF SILO TYPES ON CHEMICAL COMPOSITION AND PHYSICAL QUALITY OF SILAGE MADE FROM MAIZE, SORGHUM AND OATS FODDERS

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ABSTRACT

The objective of current study was to investigate the effects of trench, bunker and plastic bag silos on chemical and physical characteristics of silages made from three cereal fodders i.e. maize, sorghum and oats in subtropical conditions. Each fodder was harvested at 30-35% dry matter (DM) and ensiled in the said three silo types. The results revealed that trench silo had significantly ($P<0.05$) highest sensory score (smell, color and structure) followed by bunker and bag silo for each cereal silage. The sensory score for maize (12.99, 12.09 and 10.96), sorghum (11.17, 12.72, and 10.28) and oat silages (12.55, 13.27 and 11.47) corresponding to trench, bunker and bag silos, respectively. The lowest pH values were observed in trench followed by bunker and bag silos, in maize (3.61, 3.65 and 3.81), sorghum (3.71, 3.81 and 3.89) and oat silage (3.82, 3.87 and 3.93), respectively. However, the DM and crude protein (CP) were significantly ($P<0.05$) higher in trench followed by bunker and bag silos. In-vitro dry matter digestibility (IVDMD) also varied significantly ($P<0.05$) among silo types. The higher IVDMD% for maize (65.83, 64.53 and 63.00), sorghum (62.23, 60.43 and 58.00) and oats (59.60, 58.6 and 57.16) silages were observed in trench followed by bunker and bag silo, respectively. The current findings revealed that silage quality was highest in trench silo for cereal fodders in subtropical conditions.

Key words: Silo types, cereal silages, physical and chemical quality.

INTRODUCTION

High quality silage is the result of several management practices. Johnson and Harrison (2001) classified the management of silages into four categories: 1) harvesting 2) silo types 3) filling and covering, and 4) feed out period. The silo type affects physical and chemical properties of silages. Different types of silos are in practice for silage making including bunker, pile, upright, pit or trench silo and plastic bag systems.

The increased dry matter losses during ensiling period are often due to exposure to oxygen. The pile and bunker silos have higher risk of oxygen exposure as compared to bag silos due to increased surface area (Johnson and Harrison, 2001). The temperature during ensiling and feed out period also impacts the silage quality. Harrison (2001) observed that bag silo was cooler during six month ensiling period and feed out phase compared to bunker silo. Also the cost of silage production including harvesting and storage is an important factor to choose silo types. Holmes (1998) conducted the cost analysis for different silo types in USA and found that bagging system was the least cost as compared to pile, bunker or upright silo. However, such studies cannot be generalized globally as the cost of raw material could vary area to area and production cost may be different for different areas for same silo type.

Most of the silage experiments were carried out in laboratory scale silos, and little data is available mentioning the change in silage characteristics when moving from laboratory scale to large scale silos. Laboratory scale silos are usually kept at room temperature, but large scale silos are under different environmental conditions determined by the location and season (Kızılsimsek *et al*. 2005). As silage production is getting popular in Pakistan and different silo types are in practice however, the studies evaluating the effect of silo types on silage characteristics are limited.

The objective of the present study was to investigate the effects of silo types (bunker, trench/pit, and bag) on the chemical composition, fermentation characteristics and physical quality of maize, sorghum and oats silages.

MATERIALS AND METHODS

Fodder crops: The three fodder crops i.e. maize (*Zea mays L*), sorghum (*Sorghum bicolor L*) and oats (*Avena sativa*) were used for silage making. The sorghum, maize, and oats were planted during the month of June, July and November 2012, respectively on agriculture field of

Dairy Animals Training and Research Center, University of Veterinary and Animal Sciences, Ravi Campus Pattoki, Pakistan (31°1'0" North, 73°50'60" East, 186 meters elevation).

Harvesting of fodder crops: All the crops under investigation in the field were harvested after full bloom with an average dry matter of 30-35% at ensiling. For DM %, the respective fodder was randomly cut during a clear day from four different parts of the field, chopped, mixed carefully, and duplicate samples 250 g were dried in a hot oven at 60 ° C for 72 hours. The detail of planting and harvesting has been presented in Table 1. The fodders were chopped by mechanical chopper (Fimax, V-Belt Driven, MC10X, Turkey) with a chop size of about 2 cm to makes it easy for compacting the silage and removing air when loaded into silos.

Ensiling of fodders in bunker, trench and bag silos: The fodder crops were ensiled in three different silo types: 1) bunker; 2) trench/pit; 3) plastic bags. The bunker, trench and plastic bag silos had the dimensions as 30×12×6, 30×12×6 ft and 36 × 24″ with the loading capacity of 40, 40 tones, and 40 kg of fodder, respectively. The density of chopped fodder in silo (about 20 kg per cubic feet) was same for all types of silos. Fodder was filled into the silos layer by layer compacted every layer by continuous treading to remove air and the silos were sealed immediately with an air-tight cover once it was filled. After 30 days of fermentation period, the three silos were opened and samples were taken for physical quality, chemical composition fermentation characteristics and *in vitro* dry matter digestibility (IVDMD).

Physical quality of silages: For physical analysis, the quality of silages was determined by color, smell, and structure along with total flieg score described by Kilic (1986). For color evaluation, the scale 1- 4 was used on the basis of change in green color from dark brown , dark green to pale yellow; for smell , the scale 1-7 was used on the basis of repugnant putrid smell to acidic sweet pleasant smell; for structure, the scale 1-4 was used on the basis of softness of leaves and stem as well as its ability to remain intact after squeezing the silage tightly in hand and then opening from breaking into small pieces to break into two or three pieces. The same person scored the silages for smell, color and structure to avoid any bias. All the scores for color, smell and structure were added to make a cumulative score as sensory score. Flieg score was calculated using a formula (flieg Score = 220 + (2 x Dry Matter% - 15) - 40 x pH) reported by Kilics (1986).The flieg score with value 81-100, 61-80, 41-60, 21-40 and 0-20 represented the silage quality a very good, good, medium, low and poor, respectively.

Chemical composition of silages: For chemical composition, approximately, 250g sample (in triplicate) was taken from each silo type, dried in a hot-air oven (Memmert, Beschickung-Loading Model 100-800, Germany) at 60°C for 72 hours (for DM%), then ground through hammer mill (Wiley laboratory Mill, Standard Model No. 2, Arthur H. Thomas Company, USA) making particle size of about 0.5 to1mm and stored in pre labeled bottles for further laboratory analyses. Nitrogen (N) contents of samples were determined by procedure AOAC. (1990) using Kjeldahl apparatus (ID 984.13), and then multiplying the N concentration by a factor 6.25 to calculate CP. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined according to Van Soest *et al*. (1991). The gross energy of the silage samples was determined through the IKA C-2000 Bomb Calorimeter, while metabolizable energy (ME) was calculated as 63% of the gross energy (Mandal *et al,* 2003).

Fermentation Characteristics: For fermentation characteristics the pH and lactic acid content was measured in silages. Approximately 25g composite sample was taken from each silo type immediately after opening. The sample silage was mixed with 100 ml of distilled water (Hart and Horn, 1987). After hydration for 10 min using blender, the diluted material was then filtered through cheese cloth and then pH was determined by using a digital pH meter. The liquid obtained was further filtrated through Whatman 54 filter paper, centrifuged and kept at 20˚C for lactic acid determination by high pressure liquid chromatography (Muck and Dickerson, 1988).

In vitro dry matter digestibility of silages: The IVDMD trials were conducted at University of Sydney, Camden. The dried samples were taken from Pakistan to Camden by air cargo. For IVDMD study, rumen liquor (inoculant) was collected from rumen of cannulated lactating Holstein cows managed on pasture and cereal-based concentrate (9kg DM/cow/day), at Corstorphine farm, University of Sydney. The collected rumen liquor was filtered through various layers of cheese cloth and mixed with buffered minerals solution in 1:2 ratio and placed at 39˚C under O_2 free environment. Dry matter digestibility (DMD) was determined *in vitro* by batch incubation of samples in rumen liquor (Wang *et al*., 1999). All the dried samples from respective cereal silages were incubated in duplicate using ANKOM filter bags (F57 filter bags; 128 pore size 25μm, 55 mm long and 50 mm wide, New York, USA). The open side of the bag (having 0.5g ground sample) was sealed with heat sealer impulse, and then put into a 50ml dark bottle. The bottle contained 25 ml of a 2: 1 buffer: rumen fluid saturated with gas N (O2-free) with 0.5 ml cysteine sulphide reducing agent. Bottles were fitted with rubber plugs placed in an incubator (Forma Scientific, model 39419-1, Marietta, OH, USA). Incubator temperature was 39˚C and bottles were placed at a rotary shaker with 90 oscillations / min (Lab-Line Instruments Inc., Melrose Park, IL, USA). Eight bottles containing only inoculum also included in each series as a blank control. After 48 h of incubation the bags having digested sample were removed from the flasks, washed under running tap water then dried in oven at 60 ° C for 48 hours. The IVDMD% was calculated from the difference of the dry weight of sample and residues remained in the bag after 48 h of digestion divided by weight of sample×100 (Wang *et al*., 1999).

Statistical Analysis: The collected data on dependent variables were analyzed by analysis of variance, using General Linear Model procedures of SAS (SAS 9.1.3). Differences of means among main effects were compared by Fisher's least significant difference test (Steel *et al.*, 1997).

RESULTS

Physical quality and fermentation characteristics of silages: The results indicated that trench silo had highest sensory score (smell color and structure) followed by bunker and bag silo for each cereal silage (Table 2; P<0.05). The sensory score for maize silage was 12.99, 12.09 and 10.96 in trench, bunker, and bag silo respectively. Similarly, the sensory scores for sorghum and oats were 11.17, 12.72, 10.28 and 12.55, 13.27 11.47 corresponding to trench, bunker and bag silos, respectively. Also, the highest flieg score was observed in trench followed by bunker and bag silo irrespective of the cereal fodder. Flieg score for maize (118.08, 121.12 and 109.08), sorghum (110.22, 116.92 and 106) and oats silages (106.04, 108.66 and 102.66) were presented in Table 2.

The results showed that silo type had significant effect on lactic acid concentration and pH values (Table 4; P<0.05). The respective lactic acid contents for maize, sorghum and oats were (8.65, 9.19, 8.38), (6.40, 6.52 6.37) and (5.80, 5.85, 5.75) corresponding to bunker, trench and bag silos, respectively. Similarly, the lowest pH values was observed in trench followed by bunker and bag silos, in maize (3.61, 3.65 and 3.81), sorghum (3.71, 3.81 and 3.89) and oat silage (3.82, 3.87 and 3.93), respectively.

Chemical composition and In-vitro dry matter digestibility of silages: The DM and CP of silages were significantly (P<0.05) higher in trench followed by bunker and bag silos as shown in Table 3. The DM values for maze (30.26±0.04, 29.66±.08, and 28.24±0.04), sorghum (30.16±0.04, 28.81±0.10, and 28.30±0.08) and oats (28.23±0.05, 27.92±0.03, and 27.43±0.05) corresponded to trench, bunker and bag silos (Table 3).A similar pattern was also observed for CP contents in all cereal silages; however silo type did not have any effect on NDF and ADF concentration in all cereal silages (Table 3).

Silo types significantly (P<0.05) affected the IVDMD of ensiled cereals (maize, sorghum and oats). The higher IVDMD digestibility was observed in trench followed by bunker and bag silo for maize (65.83, 64.53 and 63.00), sorghum (62.23, 60.43 and 58.00) and oats (59.60, 58.6 and 57.16) silages, respectively (Table 4).

Table 1. Date of sowing and harvest for three cereal fodders.

Fodder type	Date of sowing	Date of harvest
Maize	15 July	21 October
Sorghum	15 June	19 September
Oats	15 November	28 March

Table 2. Effects of silo types on physical characteristics of cereal silages.

		Silo types			
Silages	**Parameters**	**Bunker**	**Trench**	**Bag**	**P-value**
Maize	Color	3.54±0.05^{b}	3.80±0.02^{a}	3.27±0.04^{c}	0.0004
	Smell	5.64±0.03^{a}	5.71±0.02^{a}	4.93±0.05^{b}	<.0001
	Structure	2.91±0.12^{b}	3.48±0.08^{a}	2.76±0.16^{b}	0.0187
	Sensory score	**12.09**	**12.99**	**10.96**	
	Flieg score	**118.08**	**121.12**	**109.08**	
Sorghum	Color	3.40±0.008^{b}	3.52±0.01^{a}	3.32±0.04^{b}	0.0046
	Smell	5.20±0.25^{b}	6.13±0.20^{a}	4.50±0.17^{b}	0.0046
	Structure	2.57±0.03^{b}	3.07±0.12^{a}	2.46±0.20^{b}	0.0467
	Sensory score	**11.17**	**12.72**	**10.28**	
	Flieg score	**110.22**	**116.92**	**106**	
Oats	Color	3.79±0.02^{b}	3.92±0.01^{a}	3.72±0.01^{b}	0.0014
	Smell	5.33±0.27^{a}	5.73±0.23^{a}	4.53±0.14^{b}	0.0235
	Structure	3.43±0.04^{ab}	3.62±0.10^{a}	3.22±0.05^{b}	0.0218
	Sensory score	**12.55**	**13.27**	**11.47**	
	Flieg score	**106.04**	**108.66**	**102.66**	

Means within each column followed by different superscripts are significantly different (p<0.05).

Table 3. Effects of silo types on chemical composition of cereal silages.

		Silo type			
Silages	**Parameters**	**Bunker**	**Trench**	**Bag**	**p-value**
Maize	DM%	29.66±0.08[b]	30.26±0.04[a]	28.24±0.04[c]	<.0001
	CP%	6.19±0.02[b]	6.58±0.08[a]	6.15±0.03[b]	0.0021
	NDF%	62.97±0.24[a]	63.70±0.66[a]	62.97±1.06[a]	0.7353
	ADF%	32.47±0.18[a]	32.64±0.22[a]	33.23±0.63[a]	0.4312
	ME(Mcal/kg)	2.87±0.006[b]	2.93±0.02[a]	2.85±0.005[b]	0.0238
Sorghum	DM%	28.81±0.10[b]	30.16±0.04[a]	28.30±0.08[c]	<.0001
	CP%	5.58±0.06[b]	5.85±0.05[a]	5.31±0.02[c]	0.0008
	NDF%	61.47±1.96[a]	59.84±2.01[a]	61.10±2.42[a]	0.8572
	ADF%	29.77±2.75[a]	30.02±2.49[a]	32.34±2.19[a]	0.7363
	ME(Mcal/kg	2.84±0.001[a]	2.83±0.002[a]	2.56±0.23[a]	0.3321
Oats	DM %	27.92±0.03[b]	28.23±0.05[a]	27.43±0.05[c]	<.0001
	CP %	5.70±0.04[b]	5.92±0.04[a]	5.60±0.02[b]	0.0039
	NDF %	63.11±0.43[a]	64.15±0.15[a]	61.33±2.23[a]	0.3716
	ADF %	34.22±0.52[a]	34.21±0.96[a]	33.93±0.73[a]	0.9527
	ME(Mcal/kg	2.78±0.01[b]	2.84±0.001[a]	2.82±0.002[a]	0.0099

Means within each row followed by different superscripts are significantly different ($p<0.05$).

Table 4. Effects of silo types on fermentation characteristics and IVDM of cereal silages.

		Silo types			
Silages	**Parameters**	**Bunker**	**Trench**	**Bag**	**p-value**
Maize	pH	3.65±0.01[b]	3.61±0.01[b]	3.81±0.02[a]	0.0004
	Lactic acid %	8.65±0.06[b]	9.19±0.06[a]	8.38±0.08[c]	0.0005
	IVDMD%	64.53±0.14[b]	65.83±0.33[a]	63.00±0.36[c]	0.0016
Sorghum	pH	3.81±0.005[b]	3.71±0.01[c]	3.89±0.01[a]	0.0001
	LA	6.40±0.16[a]	6.52±0.21[a]	6.37±0.13[a]	0.8020
	IVDMD%	60.43±0.44[b]	62.23±0.21[a]	58.00±0.20[c]	0.0002
Oats	pH	3.87±0.005[b]	3.82±0.01[c]	3.93±0.008[a]	0.0012
	LA	5.80±0.17[a]	5.85±0.18[a]	5.75±0.19[a]	0.9251
	IVDMD%	58.6±0.27[a]	59.60±0.36[a]	57.16±0.37[b]	0.0065

Means within each row followed by different superscripts are significantly different ($P<0.001$, 0.05).

DISCUSSION

Physical quality and fermentation characteristics of silages: The higher sensory and flieg scores, and low pH for trench silos compared to bunk and bag silos were in line with Mtengeti *et al*. (2014) who reported that overall quality (flieg score and sensory scores) of elephant grass silage ensiled in trench silos was slightly better than concrete bunker silos. They also reported low pH for trench silos. This was probably due to underground cool environment of the trench silos, whereas the bunker silos were built above the ground and were more exposed to direct changes in ambient temperatures thereby increasing chances of the walls of the silos to absorb the excess heat and cold that might have affected the normal microbial fermentation. Also, the trench silo might have facilitated better packing and compaction of forage material inside the silo. Similarly, the current findings were in agreement to Kızılsimsek *et al*. (2005) who found lower pH values in big scale silo as compared to laboratory scale silo of winter and spring leguminous and cereals silages and suggested that silages in big scale were better fermented than in laboratory. The lower pH is usually an indicative of increased lactic acid concentration thereby implying better fermentation of silages during ensiling period.

Chemical composition and In-vitro dry matter digestibility of silages: The results of present study indicating the higher DM and increased in-vitro DM digestibility in trench silo were similar to the previous studies. Mtengeti *et al*. (2014) reported that DM and CP contents were higher in elephant grass silage ensiled in trench silos compared to concrete bunker silos. Pizarro and Vera (1980) also studied the effect of silo types in maize fodder and found that DM losses were lowest (9%) in trench silo compared to bunker (25%) and clamp silos (35%). The abnormal bacterial fermentation due to change in environmental temperature could be a reason for higher DM in trench silos as those are built in ground and have more stable ambient temperature. Contrary to current findings, Johnson and Harrison (2001) reported that DM losses were higher in bunker silos than bag silos. They did not compare the trench silo with other types. Although they attributed the increased loss of DM in bunker silo to more exposed surface area to oxygen in bunker silo as compared to bag silo however, the better results in their study for bag silos could also be due to the size of bag silos as large scale silos tended to have better fermentation as describe earlier. The IVDMD results of our study were in agreement with finding of Mtengeti *et al*. (2014) who reported that elephant grass silage from trench silos had significantly higher IVDM digestibility compared to concert silo silage. They were of the view that cool environment was maintained within the underground earth pits, whereas the concrete silos built above the ground, were more exposed to direct changes in ambient temperatures. Such changes lead to absorb excessive heat through walls of silo that might have intervened the normal microbial fermentation and even increased DM losses.

Conclusion: Considering the current findings, it was concluded that trench silos were better in making silages from cereal fodders. The fodders ensiled in trench silo have better physical quality, chemical composition and fermentation characteristics. It seemed that trench silo more resistant to ambient temperature thereby improving the silage quality in sub-tropical area of Pakistan.

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