Effect of Storage System and Dry Matter Content on the Composition of Alfalfa Silage[1]

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ABSTRACT

The objectives of this study were to evaluate the effects of dry matter (DM) content and three different storage systems on the quality of alfalfa ensiled on commercial farms. Alfalfa silage samples were collected from 21 bunker silos, 20 silos that limited oxygen infiltration, and 19 tower silos on 43 commercial dairy farms. Storage system and DM content were confounded because silages from bunker silos generally were wetter than silages from O_2-limiting and tower silos. There was no effect of storage system on crude protein content of the silages. However, silage from bunker silos had higher concentrations of nonprotein N, NH_3 N, and acid detergent insoluble N than did silages from the other two storage systems. The proportion of total N in neutral detergent insoluble N minus acid detergent insoluble N was greatest in silage from O_2-limiting silos. Fiber components were affected by storage system; silage from bunker silos had the greatest concentration of acid detergent fiber and neutral detergent fiber. Concentrations of acid detergent fiber and neutral detergent fiber were higher in wetter silages from bunker silos, but DM content did not influence fiber content of silages from O_2-limiting and tower silos. Concentrations of total organic acids, acetic acid, and butyric acid were highest in silages from bunker silos. The general effects of DM on the quality of silages obtained from commercial dairy farms were similar to results obtained from laboratory-scale silos.

(**Key words**: alfalfa silage, storage system, dry matter)

Abbreviation key: **NDIN** = neutral detergent insoluble N.

INTRODUCTION

The DM content at which alfalfa is harvested for ensiling in the US varies from unwilted to greater than 70% DM, depending on management, type of storage structure, and environmental conditions (8). Despite minor effects of silage DM on total CP and fiber content, DM at ensiling can cause profound changes in N profile and fermentation products. Muck (7) found that soluble NPN, total AA, and NH_3 all decreased as DM in alfalfa silage increased. Muck (8) also reported that increasing the DM content reduced the rate and extent of fermentation in alfalfa silage and resulted in higher pH. Ishler et al. (3) recommended that alfalfa should be ensiled at 30 to 35, 35 to 40, or 45 to 60% DM when using bunker, tower, or O_2-limiting storage systems, respectively. Thus, the N profile and fermentation products of the ensiled material in different silo types would be expected to vary accordingly. Much of the research documenting the effects of DM content on the quality of alfalfa silage has been done with laboratory-scale silos (7, 8). To what extent laboratory-scale silos simulate the conditions of temperature, pressure, gaseous environment, and the subsequent microbial growth and fermentation that occur in large, commercial silos is uncertain. The objectives of this study were to evaluate the effects of storage system and DM content on the quality of alfalfa ensiled on commercial dairy farms.

MATERIALS AND METHODS

Alfalfa silage samples were collected from 21 bunker silos, from 20 silos that limited O_2 infiltration, (Harvestore®; Harvestore Products, Inc., De Kalb, IL), and from 19 tower silos on 43 commercial dairy

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farms. Samples were obtained from 18 farms in northeastern Wisconsin, 12 farms in south central Wisconsin, and 13 farms in west central Wisconsin and south central Minnesota. Within each region, the farms chosen had above average milk production and management practices. Alfalfa silage was sampled from only one silo on 32 of the farms; silage was sampled from two different silos on 6 farms, from three different silos on 4 farms, and from four different silos on 1 farm. The number of cows per herd and the DHI rolling herd average from the previous 12 mo were recorded. A 10- to 15-kg sample of silage was taken directly from the silo at each location. Samples from tower and O_2-limiting silos were taken from the unloader after it ran for 2 to 3 min; samples from bunker silos were taken from different locations in the middle of the front face of the silage, 1.5 to 2.3 m from the base of the silo. Subsamples of 0.8 to 1 kg each were placed into heavy duty freezer bags (Ziploc®; DowBrands, Indianapolis, IN). The bags were compressed to remove as much air as possible, immediately placed in an ice chest, and stored within 48 h at –20°C. One subsample was analyzed for DM, CP, ADF, NDF, ADIN, neutral detergent insoluble N (**NDIN**), and OM (1); relative feed value was computed from NDF and ADF concentrations (15). An aqueous extract (7) made from another subsample was analyzed for pH, NH_3, total AA, NPN (7), and organic acids (8). One subsample from each silo was stored in reserve at –20°C. Data were analyzed using ANOVA by the general linear models procedure of SAS (10). The statistical model included storage system and locality from which the sample was taken; however, locality was found to be nonsignificant and was deleted from the model. Mean separation was performed using least significant difference protected at $P < 0.05$. When the effect of storage system was significant for a variable, the three storage systems were compared by regressing that variable on silage DM content (13).

RESULTS AND DISCUSSION

The mean rolling herd averages were 9590, 9893, and 9668 kg of milk/yr, and mean herd sizes were 199, 183, and 322 cows, for farms with at least one

TABLE 1. Effect of storage systems on composition of alfalfa silage.[1]

Item[2]	Bunker	O_2-Limiting	Tower	RMSE[3]	$P > F$[4]
DM, %	36.8[b]	54.0[a]	49.6[a]	8.8	<0.001
OM, % of DM	88.2	89.3	88.9	1.7	0.103
CP, % of DM	19.4	20.7	19.7	2.9	0.305
NPN, % of Total N	62.3[a]	55.4[b]	55.0[b]	10.0	0.014
NH_3, % of Total N	13.11[a]	6.79[b]	7.14[b]	5.54	0.008
Total AA N, % of total N	32.3	32.2	33.3	9.2	0.269
ADF, % of DM	40.5[a]	34.9[b]	35.9[b]	4.4	<0.001
NDF, % of DM	45.8[a]	41.5[b]	41.8[b]	5.9	0.020
ADIN, % of Total N	9.74[a]	6.67[b]	6.78[b]	2.34	<0.001
ADIN, % of ADF	0.72[a]	0.63[b]	0.58[b]	0.13	0.003
NDIN, % of Total N	14.1	15.0	12.2	5.9	0.626
NDIN – ADIN, % of Total N	4.37[b]	8.34[a]	5.46[ab]	4.61	0.023
Total organic acids, % of DM	8.91[a]	4.75[b]	6.66[b]	3.05	<0.001
Succinate	0.36	0.19	0.27	0.24	0.106
Lactate	3.67[ab]	2.86[b]	4.42[a]	1.94	0.028
Formate	0.018	0.049	0.038	0.055	0.193
Acetate	2.87[a]	1.16[b]	1.46[b]	1.18	<0.001
Propionate	0.265[a]	ND[b,5]	0.012[b]	0.279	0.005
Butanediol	0.41	0.31	0.28	0.21	0.100
Ethanol	0.28	0.18	0.15	0.26	0.236
Butyrate	1.04[a]	ND[b]	0.02[b]	1.01	0.002
pH	4.84	4.87	4.69	0.34	0.077
RFV, %	121.5[b]	140.8[a]	137.9[a]	24.6	0.019

[a,b]Means within the same row without a common superscript differ ($P < 0.05$).

[1]Analytical results from 21 bunker silos (20 to 51% DM), 20 O_2-limiting silos (39 to 72% DM), and 19 tower silos (31 to 60% DM).

[2]NDIN = Neutral detergent insoluble N; RFV = relative feed value (15).

[3]Residual mean square error.

[4]Probability of an effect of storage structure.

[5]Not detected.

tower silo, one O_2-limiting silo, or one bunker silo, respectively. These production values and herd sizes were well above the mean values (rolling herd average, 6984 kg/hr; 53 cows) for the state of Wisconsin (16). These data indicated that the farms from which samples were taken likely had above average management. Silage DM content varied widely within each storage system. However, DM content of silages from bunker silos was lower than that from O_2-limiting and tower silos (Table 1), resulting in a confounding of DM with storage system. The DM contents of these silages were consistent with those recommended for the silages stored in each system

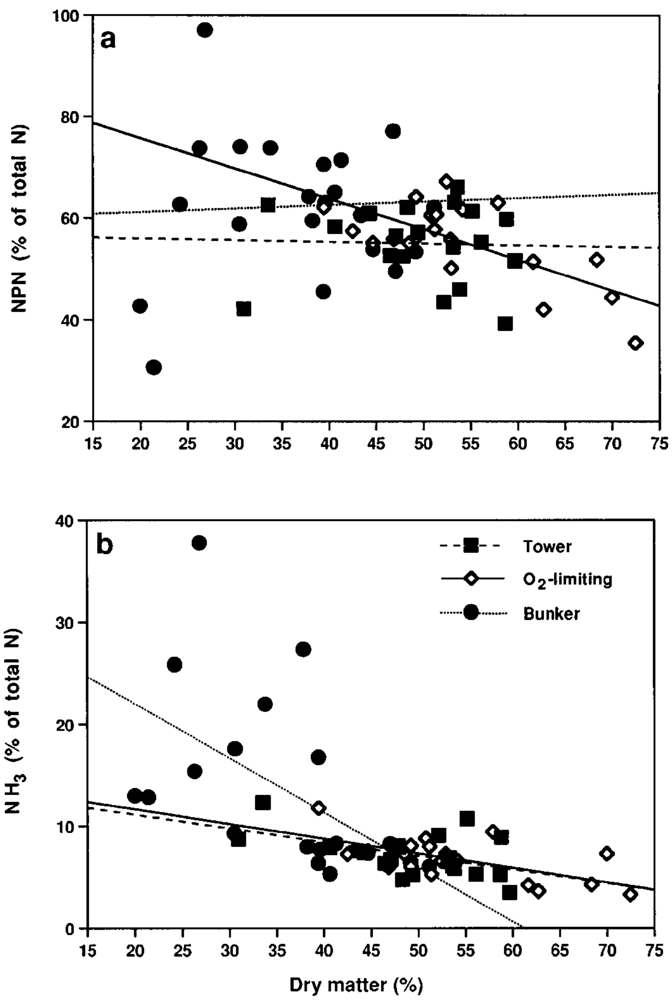

Figure 1. Regression of NPN and NH_3 (percentage of total N) on DM content of alfalfa silages from tower, O_2-limiting, and bunker alfalfa silos. Regressions obtained for tower, O_2-limiting, and bunker silos were, respectively, a) NPN = 56.57 – 0.03 DM (r^2 = 0.001), NPN = 88.47 – 0.61 DM (r^2 = 0.47), and NPN = 59.41 + 0.08 DM (r^2 = 0.002) and b) NH_3 = 13.78 – 0.13 DM (r^2 = 0.24), NH_3 = 14.5 – 0.14 DM (r^2 = 0.40), and NH_3 = 32.66 – 0.53 DM (r^2 = 0.32).

(3), which partly explained the confounding of DM content with storage system. Bunker silos tended to be used on larger farms.

The NPN content of the silages from tower and O_2-limiting silos was lower than that of silages from bunker silos (Table 1), although CP was not different. Regression of NPN on DM yielded a slope of –0.61 and a coefficient of determination of 0.47 for the O_2-limiting system, which indicated that drier forage ensiled in those structures contained less NPN (Figure 1a). Including alfalfa silage with lower NPN content in the diets of lactating dairy cows was found to improve milk production and protein yield (9). The NH_3 concentration in the silages from bunker silos was higher than that in the silages from the other two systems (Table 1). For all three silo types, slopes of regression of NH_3 on DM were negative and different from 0 ($P < 0.01$), which indicated that the formation of NH_3 during storage was reduced in drier silages (Figure 1b).

Silages stored in bunker silos were wetter and were higher in ADF and NDF than were silages stored in the other two silos (Table 1). Regressions were significant for ADF and NDF on DM only for silages from the bunker silos. Because these silages were stored in larger structures, the higher ADF and NDF contents might have resulted, in part, from a need to harvest greater acreages to fill the silos. Thus, more time might have elapsed during harvest of alfalfa stored in bunker silos, resulting in a more mature forage. However, slopes of both regressions were different from 0 ($P < 0.01$) and were negative (Figure 2, a and b), suggesting that 1) soluble components were lost in effluents from wetter silages, leaving greater concentrations of insoluble material remaining in the bunkers or 2) fermentation losses were higher in the wetter silages from bunker silos (8). At DM greater than 40% for silages from tower and O_2-limiting silos, ADF and NDF concentrations were not correlated with DM content ($r^2 < 0.01$).

Silage from bunker silos had higher ADIN concentrations than did silage from the other two storage systems (Table 1). These higher concentrations of ADIN might partly reflect the higher ADF concentration in samples from bunker silos; however, ADIN also was higher when expressed per unit of ADF, rather than per unit of N, in silage from bunker silos (Table 1). The ADIN content of silages from the three storage systems was poorly correlated with DM (Figure 3a). Goering et al. (2) reported that ADIN concentrations in fresh alfalfa were as high as 6.2% of total N and that ADIN increased to as high as 37% of total N when heated at 80°C for 24 h. Thus, formation of excess ADIN in alfalfa silage was associated with the heat generated during the ensiling process. If silage is not well compacted, or if it is stored too dry,

O_2 infiltration might cause silage to overheat (6). However, excess ADIN forms as the product of the Maillard reaction, which depends on both heat and moisture; thus, drier silage, if well compacted or otherwise restricted from O_2, likely will not overheat and cause excessive ADIN formation. Low coefficients of determination and slopes that did not differ from 0 indicated that ADIN content was not related to DM in silages from any of the three systems ($P > 0.84$). Others have found positive correlations between DM and ADIN concentration of silages: mean ADIN contents (percentage of total N) in silages from tower, O_2-limiting, and bunker silos were reported to be 19, 20, and 20% (14) and 19, 26, and 26% (11), respectively. Kung et al. (4) also detected a positive correlation of ADIN with DM content. However, silages from O_2-limiting silos were drier and had lower ADIN concentrations than did the wetter silages from other two storage systems (4). In the present study, mean ADIN concentrations ranged from 6.7 to 9.7% of total

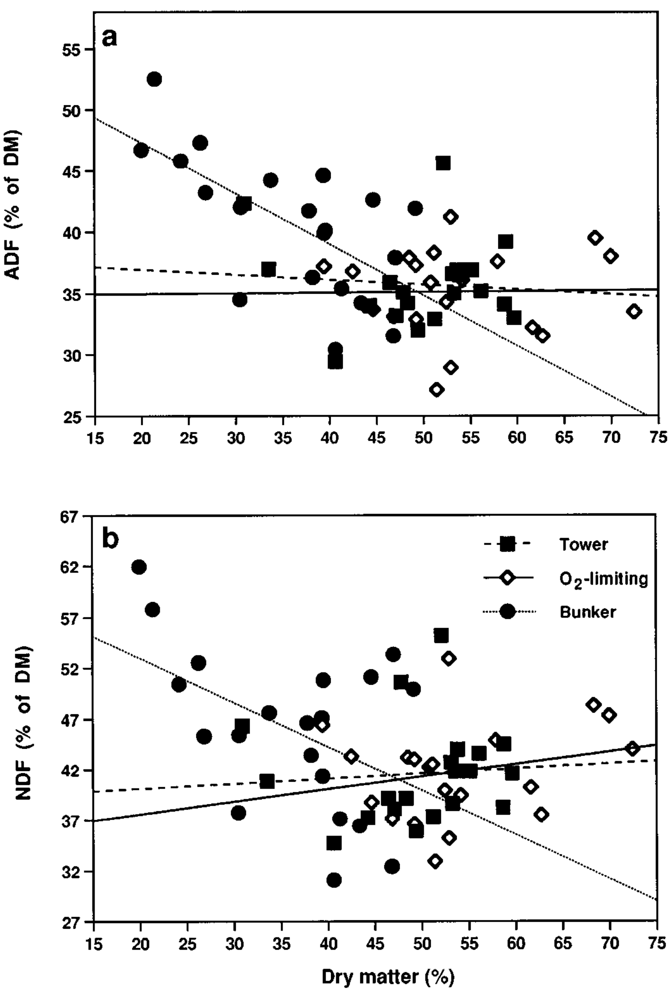

Figure 2. Regression of ADF and NDF (percentage of DM) on DM content of alfalfa silages from tower, O_2-limiting, and bunker silos. Regressions obtained for tower, O_2-limiting, and bunker silos were, respectively, a) ADF = 37.7 – 0.04 DM (r^2 = 0.01), ADF = 34.8 + 0.006 DM (r^2 < 0.001), and ADF = 55.6 – 0.42 DM (r^2 = 0.42) and b) NDF = 39.05 – 0.05 DM (r^2 = 0.01), NDF = 35.05 + 0.125 DM (r^2 = 0.05), and NDF = 61.66 – 0.435 DM (r^2 = 0.23).

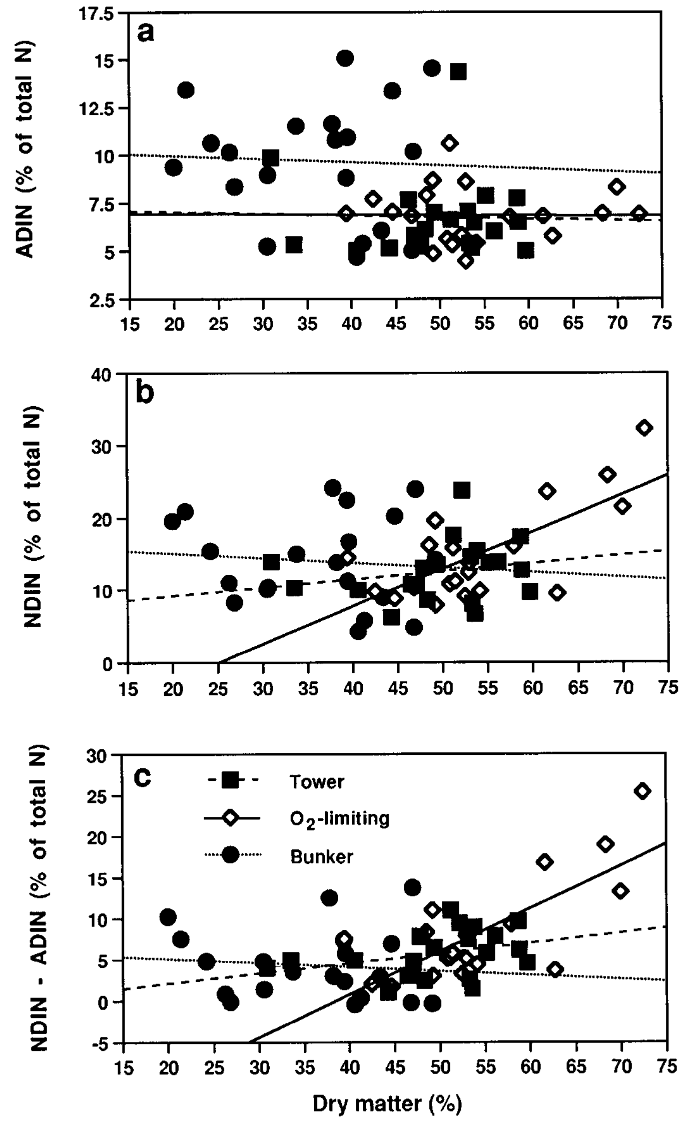

Figure 3. Regression of ADIN, neutral detergent insoluble N (NDIN), and NDIN – ADIN (percentage of total N) on DM content of alfalfa silages from tower, O_2-limiting, and bunker silos. Regressions obtained for tower, O_2-limiting, and bunker silos were, respectively, a) ADIN = 7.19 – 0.008 DM (r^2 = 0.001), ADIN = 6.97 – 0.002 DM (r^2 < 0.001), and ADIN = 10.29 – 0.017 DM (r^2 = 0.002); b) NDIN = 6.81 + 0.115 DM (r^2 = 0.05), NDIN = –13.07 + 0.519 DM (r^2 = 0.50), and NDIN = 16.4 – 0.07 DM (r^2 = 0.01); and c) NDIN – ADIN = –0.38 + 0.123 DM (r^2 = 0.11), NDIN – ADIN = –20.04 + 0.521 DM (r^2 = 0.57), and NDIN – ADIN = 6.11 – 0.05 DM (r^2 = 0.01).

N, which reflected good silage management on the farms from which silage samples were obtained.

There was a positive relationship between NDIN and DM content in silage from O_2-limiting silos (Figure 3b), which was indicated by a slope of 0.52 and a coefficient of determination of 0.50. As stated earlier, DM was confounded with storage system in this data file. However, slopes obtained by regressing NDIN on DM for silages from bunker and tower silos were 0.07 and 0.12, respectively, and were not different from 0 ($P > 0.26$), suggesting that silages with DM contents under 55% have similar NDIN contents. Sniffen et al. (12) have proposed that the difference between the NDIN and ADIN fractions represented a fraction of NDF-bound N that is degraded slowly in the rumen but is still digestible and absorbable as AA N in the small intestine. Drier silages tended to have greater amounts of the NDIN minus the ADIN fraction (Figure 3c). However, none of the silages from either the bunker or tower silos had DM contents that were greater than 59%. Thus, it cannot be determined whether the effect of DM on NDIN was due to the storage system or simply to the drier silage that was stored in the O_2-limiting structures.

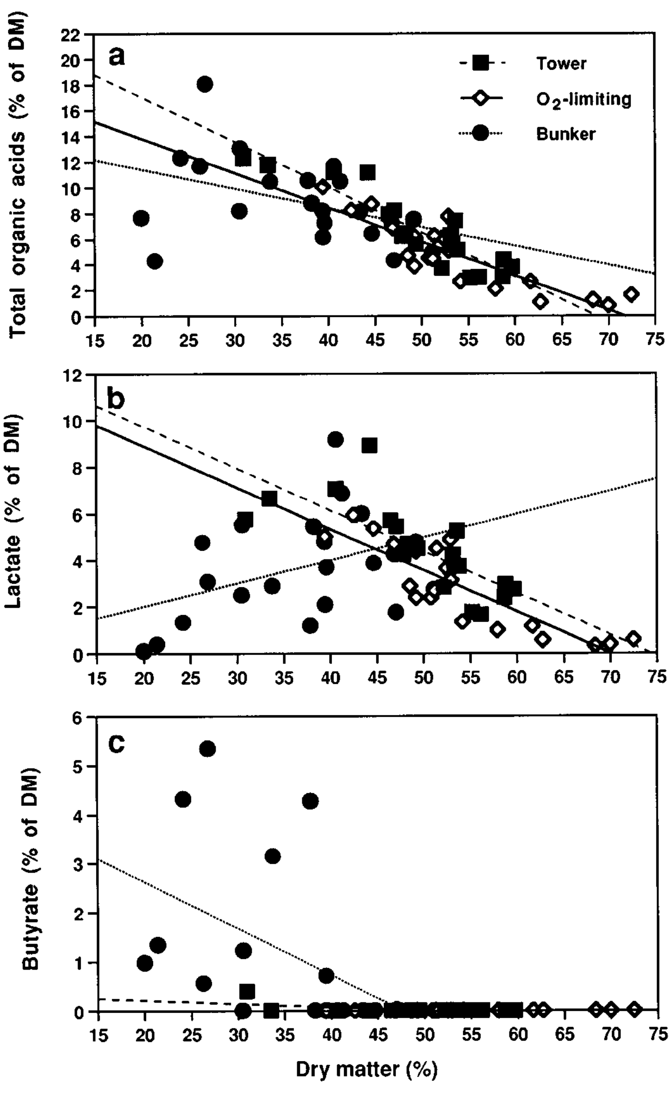

Figure 4. Regression of total organic acids, lactate, and butyrate (percentage of DM) on DM content of alfalfa silages from tower, O_2-limiting, and bunker silos. Regressions obtained for tower, O_2-limiting, and bunker silos were, respectively, a) total organic acids = 24.03 – 0.35 DM (r^2 = 0.83), total organic acids = 19.14 – 0.27 DM (r^2 = 0.76), and total organic acids = 14.39 – 0.15 DM (r^2 = 0.17); b) lactate = 13.29 – 0.18 DM (r^2 = 0.56), lactate = 12.43 – 0.18 DM (r^2 = 0.74), and lactate = 0.004 + 0.100 DM (r^2 = 0.17); and c) butyrate = 0.34 – 0.007 DM (r^2 = 0.32), butyrate = 0 DM (r^2 = 1.00), and butyrate = 4.50 – 0.094 DM (r^2 = 0.26).

As shown in Figure 4a, wetter silages had greater concentrations of total organic acids. With the exception of the two wettest silages from bunker silos, this trend was true for all three storage systems. Muck (8) reported that increasing silage DM content reduced the rate and extent of fermentation and that there were higher concentrations of acetic and succinic acids in unwilted silages. Acetic acid also was highest in silages from bunker silos (Table 1). Slopes from regression of lactic acid on DM were negative and were different from 0 ($P < 0.01$) for silages from O_2-limiting and tower silos (Figure 4b), indicating lower extents of fermentation in silages with higher DM. Regressions of lactic acid on DM for silages from bunker silos had a positive slope that was different from 0 ($P < 0.01$; Figure 4b). Concentrations of propionic and butyric acid were either very low or were not detectable in all of the silages from tower or O_2-limiting silos (Table 1; Figure 4c). However, butyric acid was present in half of the samples from bunker silos, sometimes at substantial concentrations (Figure 4c). Presence of butyric acid is an indicator of clostridial fermentation (5). Silages from bunker silos tended to increase in lactate as DM content increased, suggesting that fermentation characteristics actually improved in bunker silos as DM increased. Higher butyric acid and lower lactic acid in lower DM silages from bunker silos might reflect a shift in microbial population from lactate to butyrate production in these wetter silages. Muck (8) reported that production of lactic acid was highest at silage DM between 40 and 55% and lowest for unwilted or for drier silages. In agreement with those findings, concentrations of lactic acid were highest within that range of DM in our sample set.

The silages from tower silos tended to have lower pH (Table 1), an indication of greater fermentation.

However, silages from the bunker silos had a mean pH that was similar to silages from O_2-limiting silos, despite having the highest concentration of total organic acids (Table 1). Higher pH might have resulted from higher NH_3 concentrations in these wetter silages. Silages from bunker silos had lower relative feed values than did silages from O_2-limiting and tower silos (Table 1). Relative feed value of silages from bunker silos increased as the DM increased [relative feed value = 61 + 1.63 DM percentage (r^2 = 0.23)]; however, low coefficients of determination and slopes not different from 0 ($P > 0.33$) indicated that relative feed value was not related to DM content for silages from the O_2-limiting or tower silos. Larger farms made greater use of bunker silos. Greater variation in, and generally poorer quality of, silage from bunker silos might reflect reduced time dedicated to management of silage harvesting and storage on larger operations.

CONCLUSIONS

Despite a wide range of DM contents of the silages ensiled in each of the three storage systems, silages from bunker silos were wetter, and silages from O_2-limiting silos were drier, than silages from tower silos. No silages from bunker or tower silos had DM that was greater than 59%; no silages from tower and O_2-limiting silos had DM lower than 31 and 39%, respectively. Thus, it was not possible to conclude whether the effects of DM on silage composition were due to storage system only. However, the general effects of DM on the quality of silages obtained on commercial farms were in close agreement with results obtained in laboratory-scale silos. Based on our sample set, silage stored in bunker silos had greater amounts of NPN, NH_3, and ADIN and was of lower quality than the higher DM silages stored in tower and O_2-limiting silos. The greater variation in silage quality from bunker silos may partly reflect the lower level of management associated with that storage system than with the other two systems of forage preservation.

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