Research Note

CHANGES IN CONTENT OF SEVERAL MACRO MINERALS UPON ENSILING WHOLE PLANT CORN[1]

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This study evaluated the contents of P, K, Ca, Mg, S and ash in corn ensiled in mini-silos as the length of ensiling (LOE) increased. Whole corn plants were harvested using a self-propelled harvester outfitted with a Shredlage processor. PVC silos, of 3.0 L volume and fitted with 2-way mechanics to vent gas, were filled with about 1.9 kg of the fresh crop at about 33% dry matter (DM) and >3.1% soluble carbohydrates on a fresh matter basis. The silage fermented during prescribed periods at a temperature of 20 to 23 °C. Two representative samples of the herbage were taken before ensiling (0 d) for chemical analysis: DM, ash, P, K, Ca, Mg and S performed by wet chemistry in a commercial laboratory. After 45, 90, or 180 days of ensiling, four mini-silos were opened at each LOE and samples analyzed as above. After 45 d, P (0.29% of DM), K (1.16% of DM) and Ca (0.18% of DM) reached high points and then significantly declined after 90 d to respective values 0.25%, 1.04%, and 0.14%. Minerals were also calculated as a proportion of ash. The proportion of P, K and Ca in ash decreased significantly from day 45 to day 90 (0.07 vs. 0.059; 0.289 vs. 0.247; 0.045 vs. 0.033, respectively), yet these changes in mineral content can be considered of little biological or practical importance in animal feeding operations.

Minerals found in corn silage can be divided quantitatively into macro and trace elements. Macro minerals (P, K, Ca, Mg, S, Na and Cl) are needed in large amounts by cattle, and their functions include constituting bone and other tissues, playing a role in acid-base balance, membrane electric potential and nervous transmission (NRC, 2001). All of the essential minerals may also be detrimental or even toxic to animals if consumed in excessive amounts (NRC, 2001). Corn silage is often a major component of the diet of cattle. As such, it provides a significant proportion of the minerals consumed. The minerals provided by corn silage must be taken into account when formulating diets; therefore, understanding the impact of ensiling on mineral content is of importance to ensure that adequate amounts are provided while avoiding deficiencies or large excesses. Ash is the particulate matter that remains after the combustion of a forage sample. This analytical fraction is composed of all the mineral matter, which may include soil contamination in the forage, thus introducing the presence of silica and other non-essential minerals and raising the total ash content (Hoffman, 2005). Ash is neither created nor destroyed during the storage of silage; therefore, it has been used as an internal marker to determine silage DM losses (Bolsen et al., 2001). The objective of this study was to

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evaluate the contents of the five macro minerals: P, K, Ca, Mg and S, and of ash in corn silage fermented in laboratory mini-silos with increasing LOE.

Whole corn plants (P0636AMX, Pioneer, Johnston, IA) were harvested at a commercial dairy in South-Central Wisconsin using a self-propelled harvester (Class Jaguar 980, Class of America Inc., Omaha, NE)[5] outfitted with a Shredlage processor (Shredlage LLC, Tea, SD). The chopper was set for a theoretical length of cut (TLC) of 26 to 33 mm, which is a longer than normal TLC. Harvested forage was transported in polyethylene bags at ambient temperature. Fresh forage was inoculated at the harvester using a homo-fermentative microbial inoculant (Biomax 5, CHR. Hansen, Milwaukee, WI). Ensiling procedures were started within 2 h after harvesting. Fermentation lasted 0, 45, 90, or 180 d at a temperature of 20 to 23 °C. Mini-silos of PVC, with a volume of 3.0 L and fitted with 2-way mechanics to vent gas, were filled with about 1.9 kg of the fresh crop at about 33% DM, and >3.1% soluble carbohydrates on a fresh matter basis. Twelve mini-silos were filled so that the density of the silage in the silos was >1 kg DM per 5 L volume. Each mini-silo was closed within 15 min after being filled. Two 650 g representative samples of the herbage were taken prior to ensiling (0 d), for chemical analysis: DM, ash, and P, K, Ca, Mg and S, by wet chemistry in a properly accredited commercial laboratory (Rock River Laboratory, Watertown, WI). After 45, 90, or 180 days of ensiling, four mini-silos were opened at each LOE and samples analyzed as above. Dry matter recoveries (DMR, corrected for volatile fatty acids) were calculated by measuring differences in mini-silo weights before and after ensiling. Mineral contents were also calculated as a proportion of ash. Chemical composition and DMR data were analyzed as a completely randomized design (CRD) with four LOE replicated four times, using the General Linear Model Subroutine of SAS (2004). Least square means are presented and were separated using Tukey's Test.

There is little published information regarding the effect of ensiling on the mineral content of silages. Most of the information available involves a single time point during the ensiling period (Buchanan-Smith et al., 1974; NRC, 2001; Blackwood, 2007), which shows the importance of gathering data on mineral content at different LOE. Table 1 shows the chemical characteristics and DMR of corn silage ensiled in laboratory mini-silos for 0, 45, 90 and 180 d. The content of DM decreased ($P<0.01$) due to ensiling. Its highest value was 36.68% DM at 0 d and from there it decreased to 34.04% DM at 45 d. At this LOE point, the content of DM did not differ ($P>0.05$) from subsequent values at 90 and 180 d (32.25% and 32.51% DM, respectively). Moisture increases proportionally during ensiling due to the metabolic activity of bacteria that ferments the forage producing water and carbon dioxide along with various organic acids (Rooke and Hatfield, 2003).

Balancing minerals in dairy cow rations is of importance because of the effects on health and productivity. Manipulating the dietary cation: anion difference (DCAD; Na + K – Cl – S = mEq/100 g DM) towards negative values before calving improves blood calcium status post-calving, thus tending to prevent hypocalcemia, and increases post-calving dry matter intake and milk yield (Overton et al., 2016). Manipulating DCAD post-calving, West et al. (1992) observed that more positive ration DCAD increased the intake of DM linearly in a short-term feeding trial with lactating cows during hot, humid weather. In the present study at 0 d P comprised 0.26% of the silage DM, and this initial content did not differ ($P>0.05$) from that at any of the other LOE points. However, P in

[5]Company or trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute an endorsement by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

Table 1.—*Chemical characteristics and DMR of corn silage ensiled in laboratory mini-silos for 0, 45, 90 and 180 d.*

	Length of ensiling, d								
	0		45		90		180		
	N=2		N=4		N=4		N=4		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P<
DM, %	36.68 a[1]	1.50	34.04 ab	1.82	32.25 b	0.48	32.51 b	0.83	0.01
P, % of DM	0.26 ab	0.01	0.28 a	0.01	0.25 b	0.01	0.26 ab	0.01	0.01
K, % of DM	1.05 b	0.01	1.16 a	0.02	1.04 b	0.03	1.04 b	0.02	0.001
Ca, % of DM	0.16 ab	0.00	0.18 a	0.01	0.14 b	0.01	0.16 ab	0.01	0.002
Mg, % of DM	0.12 b	0.00	0.11 b	0.01	0.12 b	0.01	0.15 a	0.01	0.001
S, % of DM^{-}	0.11	0.02	0.10	0.00	0.10	0.01	0.11	0.00	0.93
Ash, % of DM	3.74	0.21	4.04	0.31	4.20	0.13	3.86	0.19	0.12
DMR, %	100	0	92.13	4.90	89.99	2.63	91.87	5.89	0.13

[1]Within a row, means with different letters differ P<0.05

TABLE 2.—*Proportions of macro-minerals in the ash content of corn silage ensiled for 0, 45, 90 and 180 d.*

	Length of ensiling, d								
	0		45		90		180		
	N=2		N=4		N=4		N=4		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P<
P	0.071 a[1]	0.002	0.070 a	0.007	0.059 b	0.002	0.068 a	0.003	0.019
K	0.282 a	0.006	0.289 a	0.022	0.247 b	0.008	0.270 a	0.009	0.017
Ca	0.043 a	0.003	0.045 a	0.003	0.033 b	0.001	0.041 ab	0.002	0.0001
Mg	0.033 ab	0.002	0.029 b	0.005	0.028 b	0.002	0.040 a	0.001	0.001
S	0.029	0.006	0.026	0.002	0.024	0.001	0.027	0.002	0.253

[1]Within a row, means with different letters differ $P<0.05$

DM reached a high point of 0.28% at 45 d, and then declined (P<0.05) to 0.25% values at 90 d, but did not differ from the P content at 180 d (0.26%). Potassium as % DM increased (P<0.001) from 1.05% at 0 d to 1.16% at 45 d. The content of K was similar (P>0.05) at d 0 (1.05%) and days 90 and 180 (1.04 and 1.04%, respectively). Calcium was 0.18% of the DM at 45 d, a higher value than those at 90 d (0.14%) and 180 d (0.16%), the latter two not being mutually different (P>0.05). Magnesium, content varied relatively little (P>0.05) from day 0 to day 90 (0.12% and 0.11% of DM), but then increased (P<0.05) to 0.15% at day 180. Sulfur was stable throughout all LOE varying only between 0.10 and 0.11 percent of the DM. The content of ash showed an insignificant (P>0.05) quadratic tendency with LOE and averaged 3.96% of the DM.

Dry matter recovery decreased (P>0.05) to the low values of 89.99% after 90 d of ensiling then rebounded slightly to 91.87% after 180 d. Losses in DRM are due to gas generation and the production of water by bacterial metabolic activity (Rooke and Hatfield, 2003). Ash (mineral matter) is neither created nor destroyed during the storage period of silage and this allows its use as an internal marker in silage research. In fact, ash that remains in a sample after being subjected to the acid deterrent fiber (ADF) procedure is termed acid insoluble ash (AIA) and may serve as an internal digestibility marker for in vivo experiments (Van Keulen and Young, 1977). Therefore, using ash as a basis for analysis can lead to insights in mineral content relationships. Table 2 shows the proportions of the five macro-minerals under study in the ash content of corn ensiled of LOE 0, 45, 90 and 180 d. Thus expressed, the phosphorous, potassium, and calcium contents decreased (P<0.05) from 45 to 90 d. Additionally, Ca was significantly (P<0.05) lower at day 90 (0.033) than on day 0 (0.043) and day 180 (0.041). The proportion of Mg in ash was higher (P<0.05) at day 180 (0.04) than at day 45 (0.025) and day 90 (0.028) while that proportion of S in ash was not affected (P>0.05) by LOE and averaged 0.027.

In spite of the statistical differences indicated, these changes observed in mineral content are of little biological importance, as the relative changes involved are very small. For example, the daily K consumption from silage for a cow consuming 15 kg as fed from the silages reported herein would be 57.8 g at day 0, 59.2 g at day 45, 50.3 g at day 90, and 50.7 g at day 180. Therefore, the variability in daily K intake across the LOE would be 8.9 g/d (ranging from 59.2 g/d to 50.3 g/d). In contrast, the nutritional recommendation for a cow consuming 22.68 kg DM and producing 35 kg of milk is 235.9 g K/d (NRC, 2001). Though the mineral content of corn silage is important in creating a nutrition plan, changes in mineral content due to ensiling of forage from a single field are not likely to have an impact on animal health or productivity. However, there may be a greater need for mineral content analysis on silages made from forages grown in different fields and ensiled in the same silo, as growing location may have an important impact on the mineral content.

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