Tri-State Dairy Nutrition Conference
Fort Wayne, Indiana, April 14th, 2026

Trace mineral levels influenced by soil contamination and feeding practices

A lab perspective

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Discussion Points

- Soil contamination of forages is variable
- Ash and trace mineral content of forages - Average and base levels
- Quantification of soil contamination - Use of carbon as a proxy
- Evaluating trace mineral feeding practices through mineral analysis of TMR

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Soil contamination of forages

- Introduction of soil, sand, or dust into forages during growth, harvest, or storage
- Ways of soil contamination
  - **A. Detrital contamination:** Deposition of exogenous mineral externally on the plant surface from aerosols
  - **B. Technogenic contamination:** From soil during harvesting

(Cherney et al., 2016)

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Soil contamination of forages

Impacts of soil contamination

- Dilution of energy and nutritive value of forages
- Mineral antagonism: Fe vs Cu
- Contamination of forages by soil-borne microorganisms
  - Dry matter loss during silage fermentation
  - Production of undesirable end products: butyrate, NH_3-N, and biogenic amines
  - Soil-borne *Clostridia perfringens* vs. hemorrhagic bowel syndrome in cattle
- Decreased DMI

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Soil contamination of forages

- Recognized through forage analysis as higher levels of ash and trace minerals including Al, Ti, Fe, Mn, Zn, and Cu.
  - A survey of U.S. soils showed average levels: 4.7% Al, 1.8% Fe, 31% Si
- The Fe and total ash content of forages has been commonly used as an indicator of soil contamination of forages.
- Soil contamination shows up as a difference between NDF and NDFom (organic matter basis, ash-free).
- However, these are not a reliable or precise indicators of soil contamination of forages.

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Ash and trace mineral contents of forages

Base level (uncontaminated by soil) of ash and trace minerals

- What are the base levels (uncontaminated by soil) of ash and trace minerals in commonly used forage classes?
- How we determine base ash and trace mineral levels?

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Soil contamination of forages

aNDF vs aNDFom in Forages

Feed Type	No	aNDF	aNDFom	Diff.	St. Dev. Diff
Corn Silage	8143	39.8	38.9	0.93	1.03
Legume Silage	3351	41.5	39.7	1.79	1.21
Mixed Silage	654	49.5	47.3	2.22	1.85
Grass Silage	2125	53.9	51.9	2.05	1.97
Small Grain Silage	2348	52.7	50.7	1.93	1.56
Sorghum Silage	513	54.2	51.8	2.45	1.86
Legume Hay	1849	39.7	38.0	1.67	1.62
Mixed Hay	170	53.4	50.0	3.44	3.41
Grass Hay	913	59.6	56.1	3.53	2.54

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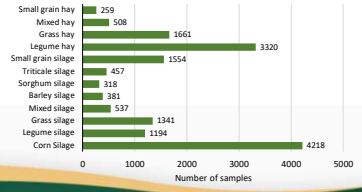
Ash and trace mineral contents of forages

Determination of base ash and trace mineral levels

- 12 different forage classes
- Determined using a data sorting approach.



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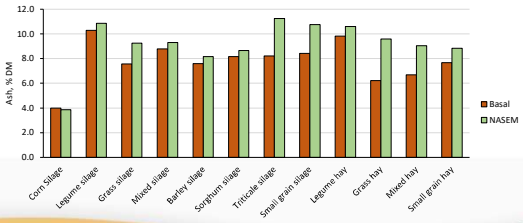
Ash and trace mineral contents of forages

Base ash contents of forages – lower 3%



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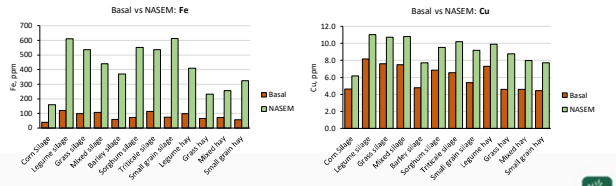
Ash and trace mineral contents of forages

Base trace minerals contents of forages – lower 3%



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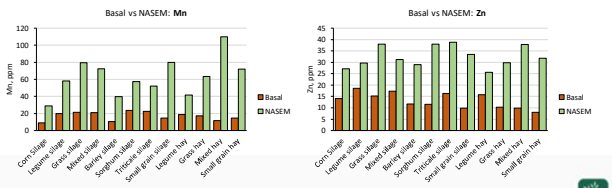
Ash and trace mineral contents of forages

Base trace minerals content of forages – lower 3%



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Soil contamination of forages

What level of trace minerals should be considered when programming?

- Base levels
- NASEM 2021 levels (or database reference levels)
- Tested levels
  - Individual test
  - Multiple test average
  - Farm average
  - Region average

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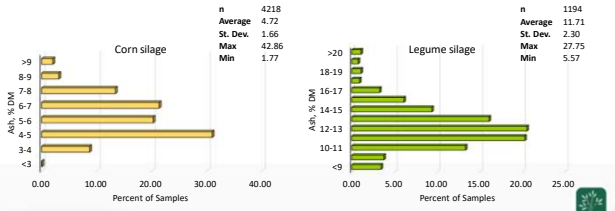
Ash and trace mineral contents of forages

Variation of ash content



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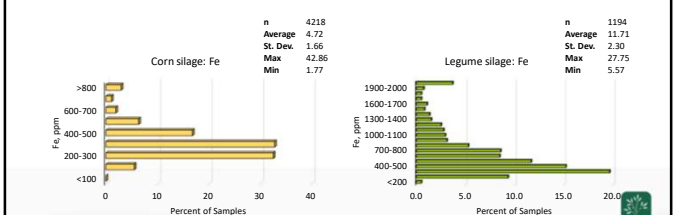
Ash and trace mineral contents of forages

Variation of Iron content



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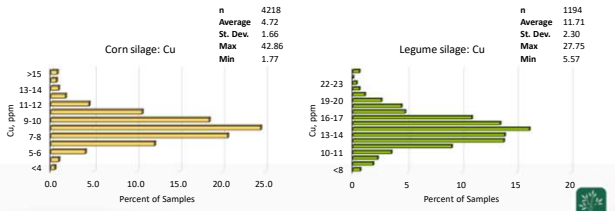
Ash and trace mineral contents of forages

Variation of Copper content



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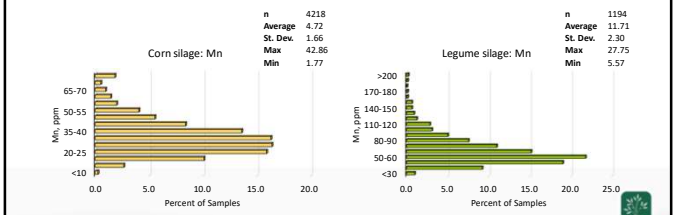
Ash and trace mineral contents of forages

Variation of Manganese content



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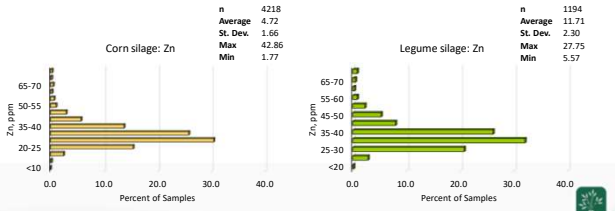
Ash and trace mineral contents of forages

Variation of Zinc content



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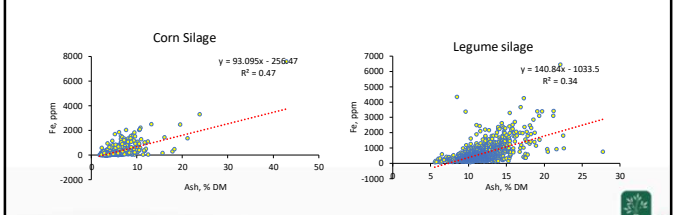
Ash and trace mineral contents of forages

Ash vs. Fe contents of forages



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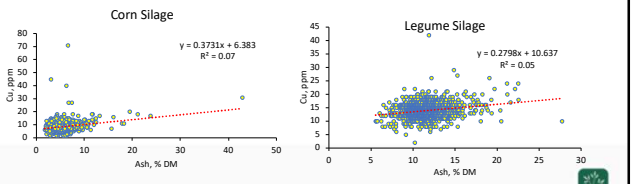
Ash and trace mineral contents of forages

Ash vs. Cu contents of forages



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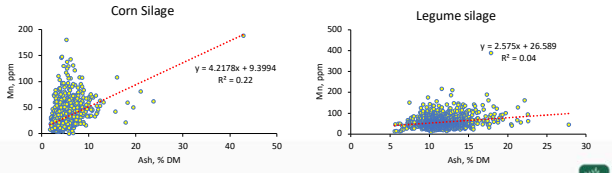
Ash and trace mineral contents of forages

Ash vs. Mn contents of forages



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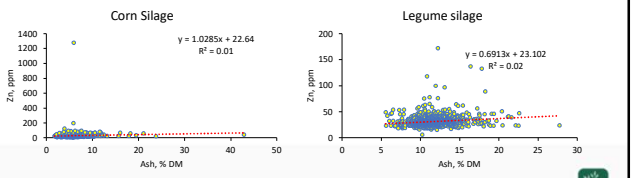
Ash and trace mineral contents of forages

Ash vs. Zn contents of forages



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Quantification of soil contamination

- No established method
- Iron (Fe) content of forages is positively correlated with ash content while Carbon (C) is negatively correlated with ash.

Objective

To compare two methods to estimate soil contamination in forages using Fe and C content of forages.

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Quantification of soil contamination

- Carbon has advantages as an indirect measure of ash and of soil contamination
  - Analytically, carbon has high precision by combustion analysis.
  - Analytically, carbon has high precision for determination by NIR analysis.
  - Differences across labs in carbon analysis are acceptable as soil contamination is defined as a relative reduction in carbon from a baseline level.

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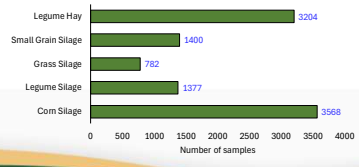
Quantification of soil contamination

Methodology

- A wet chemistry-based data set (n=10653).
- 5 different feed classes



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Quantification of soil contamination

Methodology

- *Prediction of Carbon in forages*
  - A NIR calibration was developed
    - $R^2 = 0.96$
    - SEC = 0.68
    - SD/SEC = 3.68
  - NIR Equation validation
    - $R^2 = 0.82$
    - SE = 0.94
  - The C content of forages was predicted by NIR using the developed NIR equation.

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Quantification of soil contamination

Methodology

- Prediction of base ash, Fe, and C levels of forages
  - Estimated using a data sorting approach
- Calculation of Soil contamination of forage

$$\text{Soil contamination, \%} = \frac{\text{Basal C*, \% DM - C content of the sample**, \% DM}}{\text{Basal C*, \% DM}} \times 100$$

*For Fe: Basal Fe, ppm;

**For Fe: Fe content of the sample, ppm

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Quantification of soil contamination

Results

Base Carbon and Fe content of forages

Forage class	Carbon, % DM	Fe, ppm
Corn Silage	48.2	38.2
Legume Silage	48.4	131
Grass Silage	49.0	105
Small Grain Silage	48.6	115
Legume Hay	47.0	100
Average	**48.2 ± 0.70**	

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Quantification of soil contamination

Results

Estimated average soil contamination

	% Soil contamination	
Forage class	Carbon method	Fe method
Corn Silage	4.39 ± 1.76	354 ± 456
Legume Silage	6.35 ± 2.96	346 ± 383
Grass Silage	5.99 ± 3.17	290 ± 369
Small Grain Silage	7.22 ± 3.97	468 ± 519
Legume Hay	6.32 ± 2.50	316 ± 352

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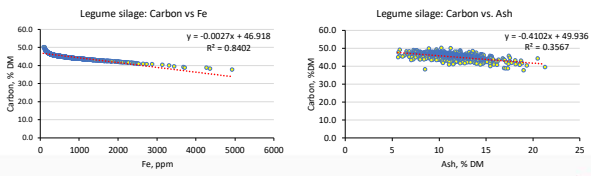
Quantification of soil contamination

Results

Legume silage



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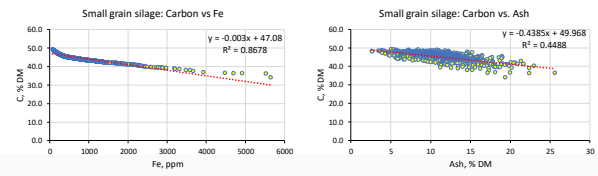
Quantification of soil contamination

Results

Small grain silage



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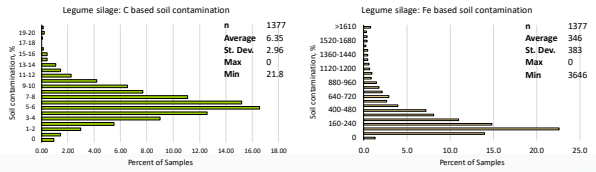
Quantification of soil contamination

Results

Distribution of soil contamination: Legume silage



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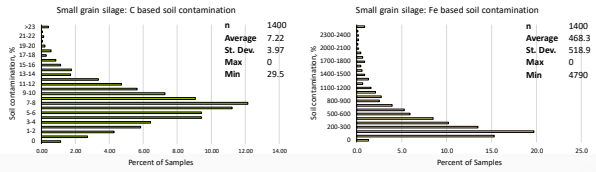
Quantification of soil contamination

Results

Distribution of soil contamination: Small grain silage



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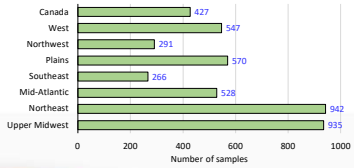
Evaluation of mineral content of Dairy TMR

Evaluation of TMR run at CVAS

Number of samples used in the evaluation



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Evaluation of mineral content of Dairy TMR

A Review of Minerals in Dairy Diets

- How do you best evaluate overall trace mineral nutrition in dairy diets?
- Evaluating trace minerals in individual forages and ingredients is costly and probably ineffective.
- TMR sampling and analysis allows for composite analysis of all inputs

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Evaluation of mineral content of Dairy TMR

A Review of Minerals in Dairy Diets

- There is variation in sampling TMR
- Taking multiple samples over time allows for establishing a baseline for trace mineral levels.
- Are trace mineral levels as expected, high, or at problematic levels?

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Evaluation of mineral content of Dairy TMR

A Review of Minerals in Dairy Diets

- A mineral analysis including trace minerals at CVAS is only $14.25 (above NIR cost)
- A mineral analysis with chloride and sulfur is $24.75 (above NIR cost)

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Evaluation of mineral content of Dairy TMR

Evaluation of TMR run at CVAS

- Focus on Dairy TMR
- Summary of 2 years of analysis by ICP and XRF
- Sample criteria
  - NDF>24 and NDF<35
  - CP>14 and CP<22
  - Limit to milk cow TMR, no dry cow or pre-fresh
  - Orts are included
  - 4506 samples with chemistry minerals, 2298 with chloride and sulfur

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Evaluation of mineral content of Dairy TMR

Milk Cow TMR

Average Nutrient Values

Item	Value
DM, %	48.4
CP, % DM	17.0
ADF, % DM	19.1
NDF, % DM	29.7
Lignin, % DM	3.53
Lignin, % NDF	11.9
Starch, % DM	25.8
Sugar (ESC), % DM	5.12
Fat, % DM	4.83
Ash, % DM	7.72

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Evaluation of mineral content of Dairy TMR

Evaluation of TMR run at CVAS

Average Values by Region

Region	Ash, % DM
Midwest	8.14
Northeast	7.19
Mid-Atlantic	7.51
Southeast	7.28
Plains	9.51
Northwest	9.35
West	8.58
Average	**8.22**
Canada	8.05

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Evaluation of mineral content of Dairy TMR

Milk Cow TMR

Average Macro Minerals

Mineral	Average	St. Dev.	COV, %
Ca, % DM	0.93	0.22	24
P, % DM	0.41	0.07	17
Mg, % DM	0.34	0.07	21
K, % DM	1.44	0.24	17
Na, % DM	0.45	0.17	38
Cl, % DM	0.50	0.15	30
S, % DM	0.25	0.06	24
DCAD, (meq/100g DM)	27.5	8.30	30

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Evaluation of mineral content of Dairy TMR

Milk Cow TMR

Average Trace Minerals

Mineral	Average	St. Dev.	COV, %
Fe, ppm	400	220	55
Mn, ppm	82.0	37.0	45
Zn, ppm	101	47.0	47
Cu, ppm	20.4	6.70	33

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Evaluation of mineral content of Dairy TMR

Evaluation of TMR run at CVAS

Average Macro Minerals in %DM by Region

Region	Ca	P	Mg	K
Upper Midwest	0.92	0.39	0.34	1.41
Northeast	0.90	0.39	0.33	1.35
Mid-Atlantic	0.91	0.38	0.33	1.46
Southeast	0.98	0.39	0.35	1.43
Plains	0.97	0.40	0.34	1.64
Northwest	0.98	0.42	0.36	1.50
West	0.93	0.46	0.38	1.39
Average	**0.94**	**0.40**	**0.35**	**1.45**
Canada	0.92	0.43	0.36	1.44

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Evaluation of mineral content of Dairy TMR

Evaluation of TMR run at CVAS

Average Sulfur in %DM by Region

Region	Number	Sulfur	St. Dev.
Upper Midwest	611	0.235	0.036
Northeast	610	0.239	0.039
Mid-Atlantic	203	0.233	0.037
Southeast	110	0.231	0.033
Plains	91	0.283	0.047
Northwest	154	0.271	0.040
West	368	0.277	0.038
Average		**0.253**	**0.039**
Canada	97	0.281	0.057

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Evaluation of mineral content of Dairy TMR

Average Trace Minerals in ppm by Region
Top 15% in Parenthesis

Region	Fe	Mn	Zn	Cu
Upper Midwest	386 (712)	91 (136)	100 (152)	20 (28)
Northeast	328 (508)	69 (105)	92 (125)	21 (29)
Mid-Atlantic	348 (639)	81 (159)	87 (146)	21 (31)
Southeast	347 (588)	92 (133)	-	22 (32)
Plains	554 (1066)	93 (140)	121 (229)	21 (32)
Northwest	510 (934)	73 (112)	79 (118)	19 (29)
West	403 (716)	66 (104)	85 (133)	17 (28)
Average	**386**	**80**	**105**	**20**
Canada	401 (722)	92 (128)	106 (155)	24 (41)

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Evaluation of mineral content of Dairy TMR

Conclusions

- TMR mineral analysis, despite sampling variation, is a means of evaluating mineral and trace mineral feeding levels in rations without the need to test individual ingredients composing rations.
- Average mineral levels fed do not vary significantly by region in most cases.
- Fe is higher in the Plains and Northwest regions - greater soil contamination.
- Zn levels appear higher in several regions - contamination or supplementation?
- Sulfur levels appear higher in the Plains, Northwest and Western regions, probably due to a higher level of byproducts being fed.

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Quantification of soil contamination

Conclusions

- Soil contamination is an inherent characteristic of forage quality and should be evaluated to inform feeding decisions and forage production practices.
- Trace minerals are not a reliable proxy for estimating soil contamination.
- The use of carbon analysis data by NIR may be a productive approach to estimating forage soil contamination levels.

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Tri-State Dairy Nutrition Conference
Fort Wayne, Indiana, April 14th, 2026

Thank you!

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