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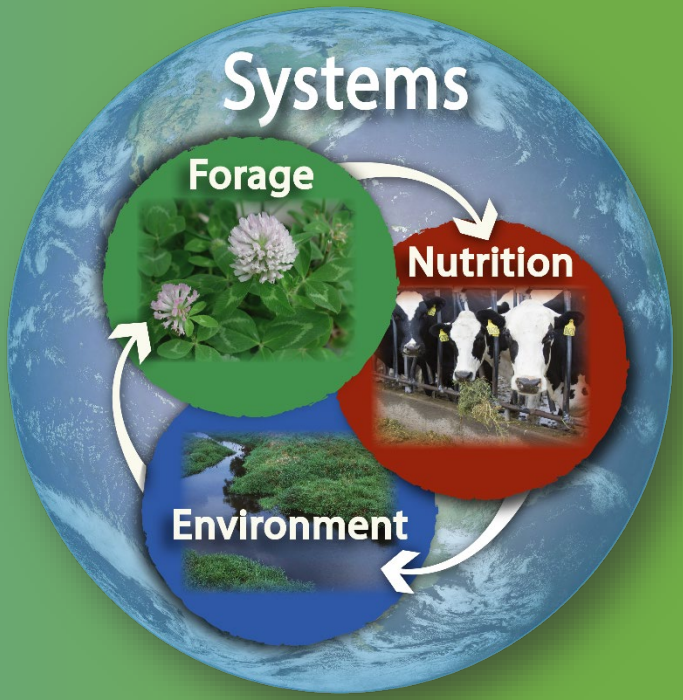
Silage Production and Utilization in the USA



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USDA - Agricultural Research Service

Outline

1. Silage utilization in the U.S.

2. Formulation of silages into lactating dairy cow diets

3. Limitations and opportunities

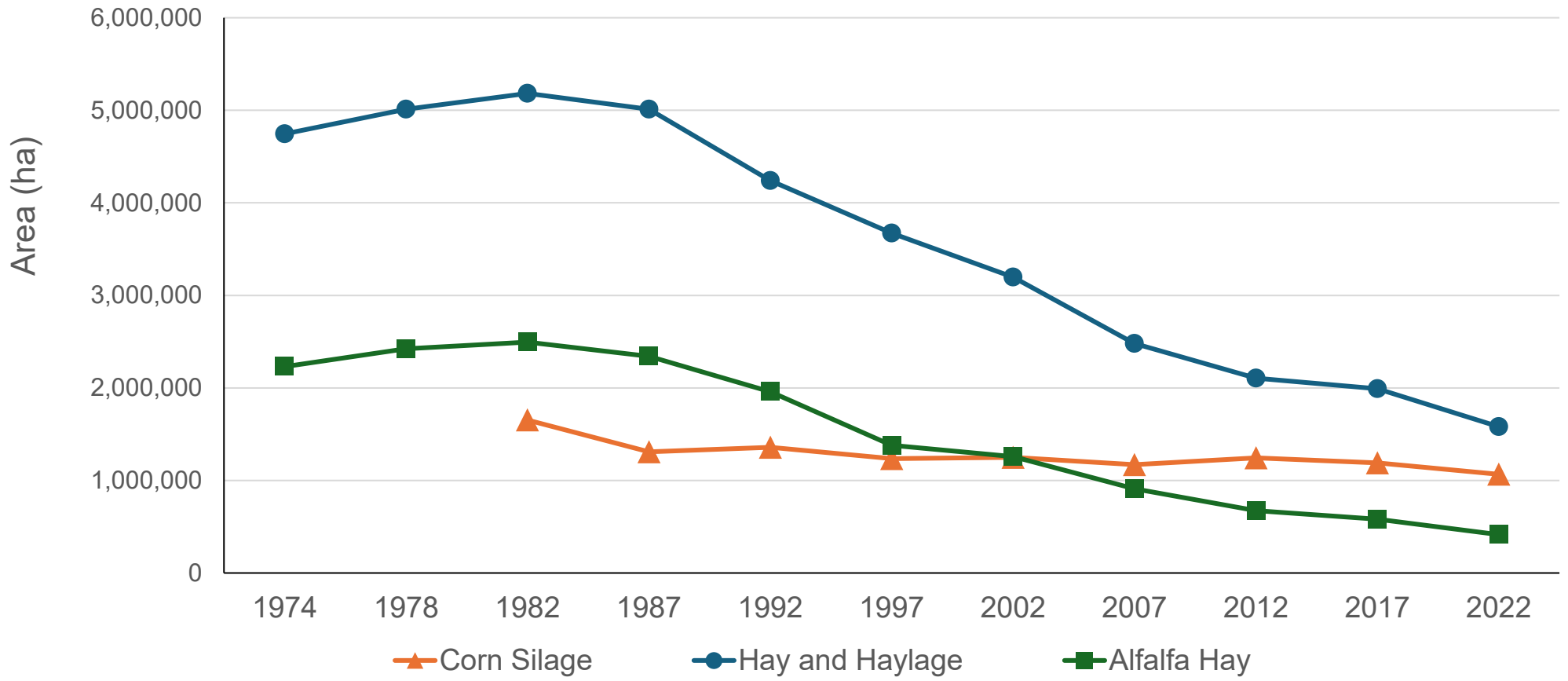
1. Silage Utilization in the U.S.

Silage utilization in the U.S.

- Choice of forages for silage in the dairy ration vary depending on climate, soil types and growing conditions of that region.

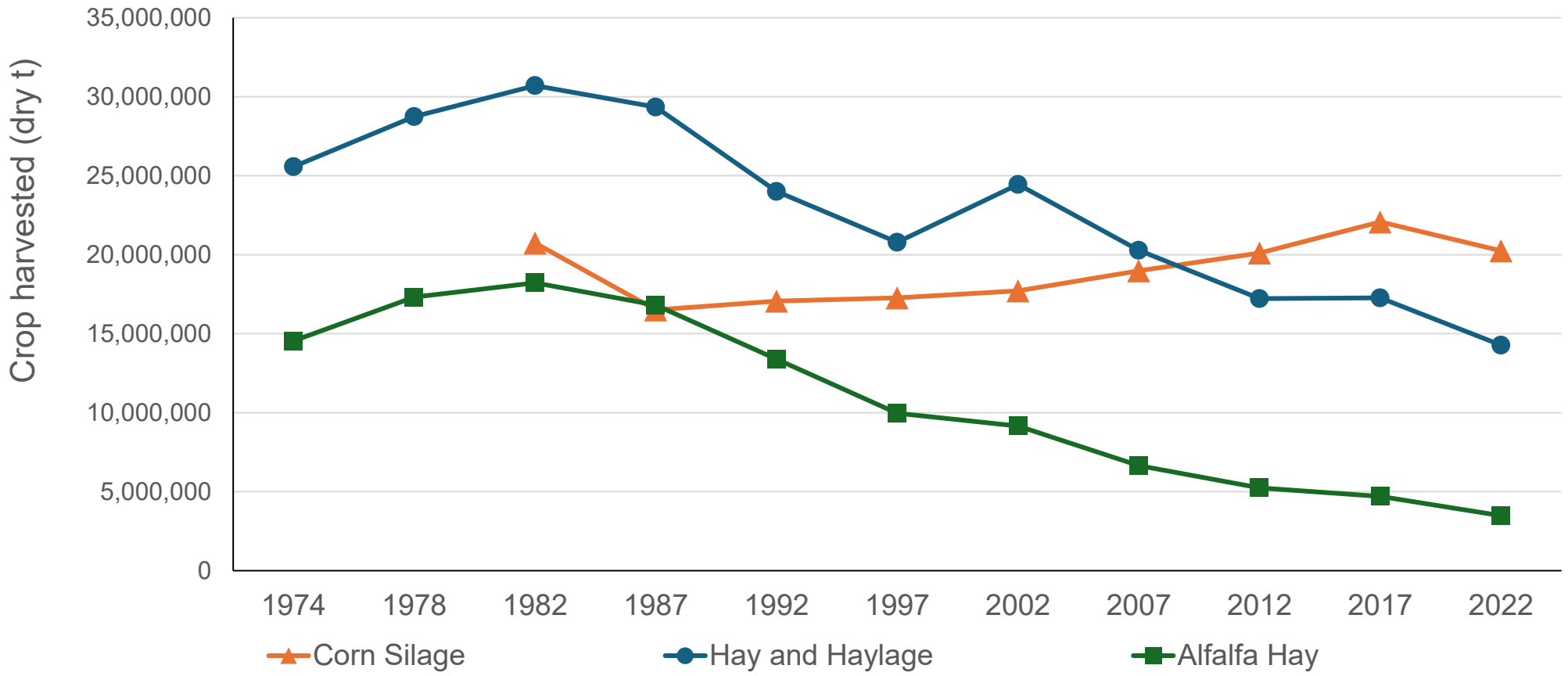
- What types of forages for silages are commonly used in the U.S.?

Land Use for Silage and Hay Crops on U.S. Dairy Farms



Martin et al. (2017); NASS (2025)

Crop Harvested for Silage and Hay Crops on U.S. Dairy Farms



Martin et al. (2017); NASS (2025)

Silage utilization in the U.S.

- In much of the U.S., corn silage is the dominant silage used in dairy cow rations. And it's growing. Why?

Silage utilization in the U.S.

- In much of the U.S., corn silage is the dominant silage used in dairy cow rations. And it's growing. Why?
  - Higher biomass yield
  - Higher energy forage
  - Management – less harvesting time and labor, more consistent quality

Silage utilization in the U.S.

- 2nd most popular
  - Alfalfa silage
- Dry climates of southwest U.S.
  - Forage sorghum silage
- Additional silage crops
  - Grass silages
  - Annual grain silages
  - Cover crop silages

2. Increasing the use of silages in lactating dairy cow diets

Why is silage important in dairy cow diets?

- **Silages are critical for providing necessary fiber for dairy cow diets**
  - Provides energy
  - Regulates the intake of feed
  - Stimulates chewing, saliva production, and rumination
  - Increases buffering of the rumen
  - Regulates rumen function
  - Provides a source of precursors for milk fat

Additional reasons to increase silage in diets of lactating dairy cows

1. There is a need to increase animal productivity to meet the increasing demand for animal-sourced food.
2. Increase utilization of feeds that are not in direct competition with human food, monogastric feed, and biofuel feedstock.
3. Lower the cost of the diet.

How can we increase silage utilization?

Methods to improve NDF digestibility to increase silage utilization in dairy cow diets

- Physical treatments
  - Chopping, shredding, grinding, pelleting, steaming
- Biological treatments
  - Enzymes, inoculants, yeast, fungi
- Chemical treatments
  - Acids, hydrolyzing alkalis
- Genetic technologies
  - Variety selections available to producers

Adesogan et al. 2019. Symposium Review: Technologies for improving fiber utilization. J. Dairy Sci. 102:5726-5755.

Inclusion of high-quality alfalfa silage in dairy cow diets

Experiment materials and methods

- 48 Holstein cows (24 primiparous, 24 multiparous)
- Randomized complete block design
  - 2-week common covariate diet
  - Followed by 8-week treatment diet
- Cows milked 3× per day and individually fed in a tie-stall barn
- High quality alfalfa silage was included to the base diet at 0, 6, 12, and 18% of the diet (DM basis) concentrate feedstuffs

Engel et al. (2020)

Diets

	Forage %			
Ingredient (% of DM)	50%	56%	62%	68%
BMR corn silage	40	40	40	40
3rd cut alfalfa silage	10	10	10	10
4th cut alfalfa silage	0	6	12	18
High moisture corn	17	17	17	17
Soybean meal	9.3	6.2	3.1	0
Expleller SBM	2.7	4.8	6.9	9.0
Roasted soybeans	2.0	2.0	2.0	2.0
Soybean hulls	15	10	5	0
Blood meal	0.70	0.97	1.23	1.50
Urea	0.39	0.26	0.13	0
Vit/Min + limestone	2.95	2.80	2.65	2.50

Nutrient composition

	Forage %			
Nutrient, % of DM	50%	56%	62%	68%
DM, % of diet	47.8	45.2	43.1	40.7
CP	16.8	17.0	17.1	17.2
aNDF	31.1	30.0	29.0	27.9
Forage NDF	19.2	21.2	23.2	25.2
Starch	27.6	27.6	27.6	27.6
EE	2.93	3.07	3.20	3.33
Ash	7.38	7.52	7.54	7.82

Engel et al. (2020)

Intake

	Forage %					Contrast
Item	50%	56%	62%	68%	SEM	*P*[a]
DMI, kg/d	26.3	26.5	25.4	24.9	0.37	L
NDFI, kg/d	8.18	7.95	7.37	6.80	0.12	L
Forage NDF, kg/d	5.06	5.60	5.89	6.16	0.09	L

[a]L = Linear response ($P<0.05$); Q = Quadratic response ($P<0.05$).

Engel et al. (2020)

Lactation performance

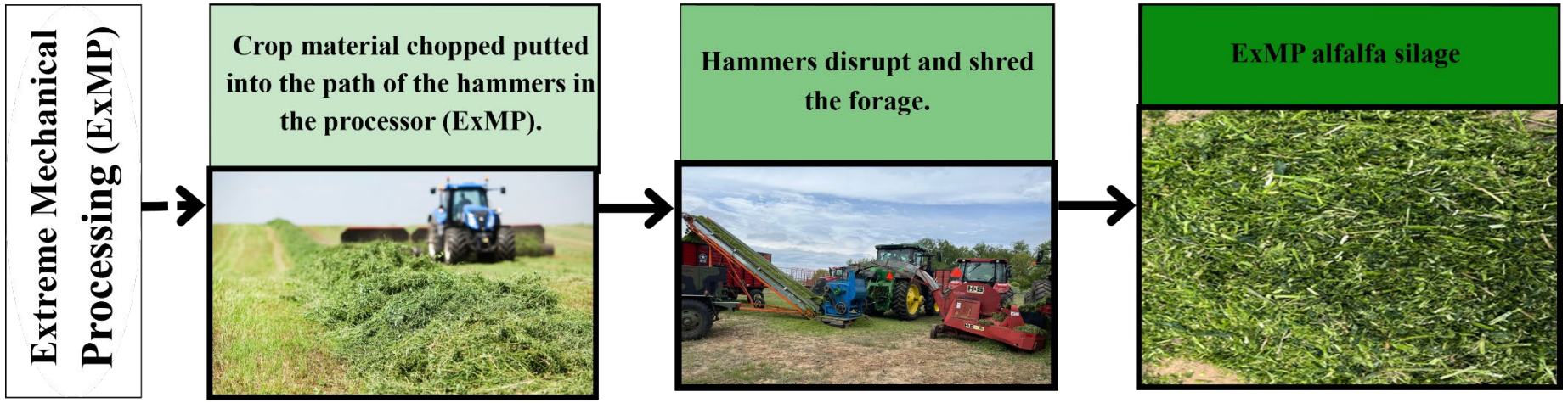
	Forage %					Contrast
Item	50%	56%	62%	68%	SEM	*P*[a]
Milk, kg/d	43.7	43.0	43.3	42.5	0.74	NS
Fat, %	3.35	3.76	3.72	3.90	0.07	L
Fat, kg/d	1.48	1.61	1.62	1.65	0.04	L
Protein, %	3.02	3.03	3.01	2.99	0.02	NS
Protein, kg/d	1.32	1.31	1.30	1.27	0.02	LT
MUN, mg/dL	14.2	13.7	13.5	13.5	0.39	NS
ECM, kg/d	43.0	44.2	44.5	44.3	0.81	NS
ECM/DMI	1.63	1.69	1.75	1.83	0.03	L

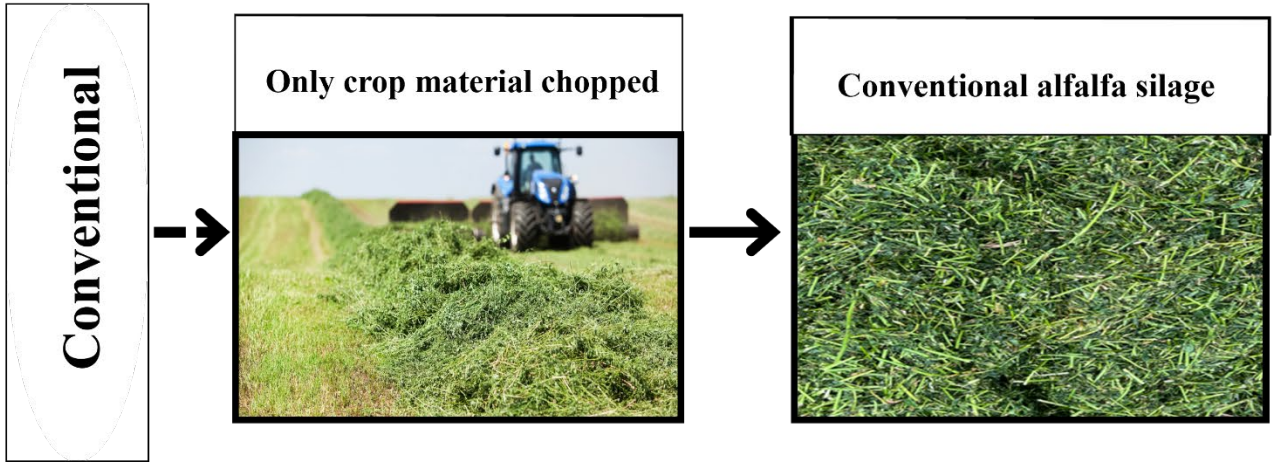
[a]L = Linear response ($P<0.05$); LT = Linear trend ($P<0.10$); Q = Quadratic response ($P<0.05$).

Engel et al. (2020)

Processing of forages to increase utilization

Extreme mechanical processing (ExMP) of forages





Montes et al. (2025)

Extreme mechanical processing (ExMP) of forages

ExMP **CONVENTIONAL**

Experiment materials and methods

- 36 Holstein cows (14 primiparous, 22 multiparous)
- Randomized complete block design
  - 2-week common covariate diet
  - Followed by 6-week treatment diet
- Cows milked 3× per day and individually fed in a tie-stall barn
- Extreme processed alfalfa silage was compared to a non-processed control alfalfa silage

Kennedy et al. (2025)

Ingredient composition

Ingredient, % of DM	Control	ExMP
Control alfalfa silage	29.0±1.27	0
ExMP alfalfa silage	0	27.9±0.66
BMR corn silage	31.0±0.70	31.4±0.61
High-moisture corn	19.9±0.60	20.2±0.41
Canola meal	7.9±0.12	8.7±0.09
Roasted soybeans	4.0±0.08	4.1±0.05
Soybean hulls	5.5±0.08	5.6±0.09
Mineral and vitamins	2.7±0.08	2.7±0.03

[1]Control = control diet; ExMP = extreme mechanical processed diet.

Kennedy et al. (2025)

Nutrient composition

Nutrient, % of DM	Control	ExMP
DM	44.9	44.3
CP	16.7	16.3
NDF	29.3	28.8
Forage NDF	21.4	20.7
ADF	20.9	21.1
Starch	27.6	27.9
Ether extract	3.70	3.74
Ash	6.0	5.9

[1]Control = control diet; ExMP = extreme mechanical processed diet.

Kennedy et al. (2025)

Total tract nutrient digestibility

Item, % of DM	Control	ExMP	SEM	P-value
DM	67.7	72.4	0.80	<0.01
OM	67.8	72.3	0.80	<0.01
NDF	39.9	51.8	1.64	<0.01
ADF	44.4	49.5	1.55	0.03
CP	67.8	71.2	0.79	0.01
Starch	96.6	97.2	0.21	0.03

[1]Control = control diet; ExMP = extreme mechanical processed diet.

Kennedy et al. (2025)

Lactation performance

Item, % of DM	Control	ExMP	SEM	P-value
Intake, kg/d	28.0	27.3	0.30	0.13
Milk yield, kg/d	46.1	46.8	0.41	0.21
Fat, %	3.81	3.93	0.04	0.03
Fat, kg/d	1.75	1.83	0.04	0.01
Protein, %	3.09	3.10	0.01	0.42
Protein, kg/d	1.42	1.45	0.01	0.13
ECM, kg/d	48.0	49.5	0.46	0.03
ECM/DMI	1.71	1.81	0.02	0.01

[1]Control = control diet; ExMP = extreme mechanical processed diet.

Kennedy et al. (2025)

Use of cover crops in dairy cow diets

Current cover crop experiments at DFRC

Rye - monoculture

Triticale - monoculture

Rye-vetch-camelina 3-way mix

Triticale-vetch-camelina 3-way mix

Nutrient composition of cover crops - DFRC

Nutrient, % of DM	Alfalfa	Rye mono	Triticale mono	Rye 3-way[1]	Triticale 3-way[1]
CP	**23.9**	**13.0**	**11.5**	**13.6**	**11.1**
aNDFom	35.4	57.7	52.5	53.9	50.7
ADF	30.4	38.5	34.5	37.3	35.5
Lignin (ADL)	5.84	1.95	1.80	1.87	2.73
NDFD30, % of NDF	47.7	74.0	73.8	71.3	68.2
Sugar	3.07	2.58	2.44	2.95	3.44
Starch	2.68	0.37	0.31	0.30	0.44
Fat	4.08	4.59	6.00	4.91	5.16
Ash	10.31	9.97	8.93	9.38	8.84

[1]3-way mix included rye or triticale with hairy vetch and camelina.
Rye-mono and Rye-3-way were harvested May 12th 2023 &Triticale-mono and Trit-3-way were harvested May 23rd 2023

Recent experiment at DFRC

- Experiment – Inclusion of cover crops in high production lactating dairy cow diets.
  - 65 Holstein cows at peak milk production (60-150 DIM).
  - Cows were fed 1 of 5 diets:
    - Control – traditional corn silage/alfalfa silage (AS) diet
    - Rye mono – included at 15% of the diet (replacing AS)
    - Triticale mono – included at 15% of the diet
    - Rye 3-way – included at 15% of the diet
    - Triticale 3-way – included at 15% of the diet
  - Fed diets for 8 weeks to determine effects of cover crop silage on intake, milk yield, milk composition, nutrient digestibility, and methane production.

Ingredient composition of diets - DFRC

Nutrient, % of DM	Control	Rye mono	Triticale mono	Rye 3-way[1]	Triticale 3-way[1]
Corn silage	30	30	30	30	30
Alfalfa silage	30	15	15	15	15
Cover crop silage	0	15	15	15	15
High-moisture corn	19	19	19	19	19
Canola meal	5	7	8	7	8
Soybean hulls	4	2	1	2	1
Roasted soybeans	4	4	4	4	4
Expeller SBM	4	4	4	4	4
Minerals and vit.	2.5	2.5	2.5	2.5	2.5
GreenFeed pellets	1.5	1.5	1.5	1.5	1.5

[1]3-way mix included rye or triticale with hairy vetch and camelina.

Nutrient composition of diets - DFRC

Nutrient, % of DM	Control	Rye mono	Triticale mono	Rye 3-way[1]	Triticale 3-way[1]
CP	16.8	16.2	16.3	16.3	16.3
aNDFom	29.5	31.4	30.2	30.8	29.9
ADF	22.6	22.2	21.3	22.0	21.4
Lignin (ADL)	3.03	2.46	2.51	2.45	2.64
Starch	24.6	24.6	24.6	24.6	24.7
Ether extract	4.8	4.7	4.9	4.7	4.8
Ash	5.7	5.6	5.5	5.6	5.5

[1]3-way mix included rye or triticale with hairy vetch and camelina.

Preliminary results!

Item	Control	Rye mono	Triticale mono	Rye 3-way[1]	Triticale 3-way[1]	SEM	P-value
DMI, kg/d	24.2	23.5	23.8	23.8	24.3	0.32	NS
Milk, kg/d	39.3	38.4	38.6	38.8	39.6	0.48	NS
Fat, %	4.16	4.11	4.23	4.20	4.15	0.05	NS
Protein, %	3.02	3.09	3.12	3.02	3.05	0.03	Con vs CC^{T} Mono vs 3-way
Total solids, %	13.08	13.04	13.23	13.10	13.09	0.06	NS
MUN, mg/dl	12.6	12.1	12.1	12.3	11.9	0.17	Con vs CC

[1]3-way mix included rye or triticale with hairy vetch and camelina.
P-values < 0.05 unless noted with a superscript T, 0.05 < P < 0.10.

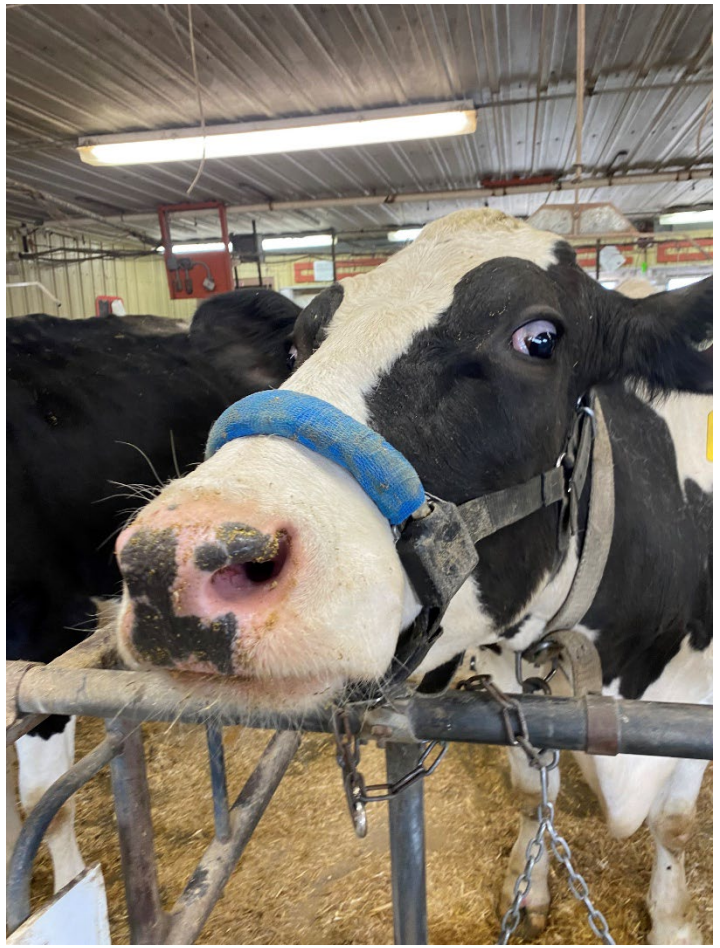
Preliminary results!

Item	Control	Rye mono	Triticale mono	Rye 3-way[1]	Triticale 3-way[1]	SEM	P-value
Fat yield, kg/d	1.63	1.57	1.63	1.62	1.63	0.02	NS
Prot yield, kg/d	1.18	1.18	1.20	1.17	1.20	0.02	Rye vs trit[T]
ECM, kg/d	42.5	41.4	42.5	42.0	42.7	0.49	Rye vs trit[T]
FE[2] (ECM/DMI)	1.75	1.77	1.76	1.78	1.77	0.024	NS

[1]3-way mix included rye or triticale with hairy vetch and camelina.
[2]FE = Feed efficiency.
P-values < 0.05 unless noted with a superscript T, 0.05 < P < 0.10.

Recent experiment at DFRC – Part II

- Experiment 2 – Inclusion of cover crops in early lactation dairy cow diets.
  - 80 Holstein cows enrolled at week 3 (23±3 DIM).
  - Cows were fed 1 of 5 diets:
    - Control – traditional corn silage/alfalfa silage (AS) diet
    - Rye mono – included at 10% of the diet (replacing AS)
    - Triticale mono – included at 10% of the diet
    - Rye 3-way – included at 10% of the diet
    - Triticale 3-way – included at 10% of the diet
  - Diets formulated to be iso-energetic and iso-nitrogenous at 18% CP, 30% NDF, 26% starch (DM basis).
  - Fed diets for 10 weeks to determine effects of cover crop silage on intake, milk yield, milk composition, nutrient digestibility, and methane production.



Recent experiment at DFRC – Part II

- SUMMARY:
  - Intake did not differ between treatments
  - Average milk yield was greater for cows fed Rye diets (53.5 kg/d) vs. Trit diets (48.6 kg/d)
  - Milk protein % was greater for cows fed Trit diets (3.05%) vs. Rye diets (2.92%)
- CONCLUSION:
  - Cover crops can successfully be fed at 10% of the diet (DM basis) in early lactation and at least 15% of the diet in mid to late lactation.

3. Challenges and Opportunities

Challenges and Opportunities

- **Challenges**
  - Increasing silage in diets may decrease intake which may or may not result in reduced performance, however….
- **Opportunities**
  - Increasing silages in diets have been shown to increase feed conversion efficiency.
  - Processing of forages can improve digestibility resulting in improved productivity.
  - Alternative forages such as cover crops can successfully replace traditional forages without decreasing production.

QUESTIONS?

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Increasing forage inclusion in dairy cow diets

Improving feed conversion efficiency with silage

Impact of increasing forage (70% corn silage:30% alfalfa silage)

	Forage %					Contrast
Item	42F	50F	58F	66F	SEM	*P*[a]
DMI, kg	28.0	27.0	25.8	24.8	0.69	L
Milk, kg	40.1	40.4	40.8	39.1	1.12	NS
ECM, kg/d	38.0	38.4	39.5	38.7	1.23	NS
FE (ECM/DMI)	1.36	1.44	1.54	1.57	0.047	L

[a] L=Linear response ($P<0.05$).

Schuler et al., 2013