2014 Research Report:

Hydroponic Barley Fodder as a Grain Alternative in the Organic Dairy Ration

Funded in part by:

California Agriculture Research Institute, CSU Chico Research Foundation & Simply Country, Inc., www.simplycountry.net

C.A. Daley, Ph.D.; Celina Phillips, Ph.D.; Darby Heffner and Breanna Roque - College of Agriculture
California State University Chico, Organic Dairy Program

What is fodder?

- Grain is soaked in water and placed in trays to allow seeds to germinate and “sprout” for 5 to 6 days

- Has been used for centuries in Asian countries to improve feed quality for livestock

Why study fodder?

- Assess value as an alternative source feed
- Can fodder serve as a grain substitute
- Determine feasibility and cost effectiveness
- Very little has been done

Agri-Dynamics – J. Brunetti

SPROUTING GRAINS

Sprouting Grain Makes Cereals More Nutritious

- Converts starch to sugar (better rumen energy, less acidosis)
- Converts soluble protein to "by pass" protein (less rumen ammonia, BUN, MUN)
- Neutralizes Phytates (aka phytic acid) which inhibit mineral absorption
- Destroys Enzyme Inhibitors (which compromise digestion)
- Increases Enzyme Levels (for better digestion and absorption)
- Increases Vitamin Levels
- Increases Amino Acids (quality protein)
- Increases Fatty Acids (quality energy)

FIVE DAY SPROUT ANALYSIS

ID#	*Sample*	**%NSC*	***% Sugar*	****% Starch*	*% Protein Solubility*
R218	Sprouted Conventional Corn	82.34	2.13	80.21	10.00
R228	Unsprouted Conventional Corn	71.13	2.11	69.02	13.30
R219	Sprouted Organic Corn	80.85	2.75	78.10	9.00
R227	Unsprouted Organic Corn	77.82	3.30	74.52	17.20
R220	Sprouted Organic Wheat	72.55	24.23	48.32	36.90
R234	Unsprouted Organic Wheat	74.75	3.42	71.33	35.10
R221	Sprouted Organic Barley	65.17	5.47	59.70	8.00
R229	Unsprouted Organic Barley	52.90	1.78	51.12	13.80
R222	Sprouted Conventional Oats	52.05	4.62	47.43	20.10
R232	Unsprouted Conventional Oats	56.63	1.83	54.80	42.30
R223	Sprouted Organic Oats	52.20	3.48	48.72	23.60
R233	Unsprouted Organic Oats	53.17	2.37	50.80	39.50
R224	Sprouted Conventional Rye	70.53	40.38	30.15	38.90
R231	Unsprouted Conventional Rye	71.93	5.90	66.03	43.30
R226	Sprouted Conventional Bucwheat	52.03	9.64	42.39	21.30
R230	Unsprouted Conventional Bucwheat	56.45	1.75	54.70	45.50
R225	Sprouted Conventional Sunflower	12.71	1.80	10.91	33.50

* NSC Non Structural Carbohydrates = Total of starch and sugar

**Sugars consist of: sucrose, fructans, fructose, glucose, and lactose extracted from feed by stirring in water 39°C for (1) hour.

***Starch consists of: Starch plus other sugars not extracted at 39°C in water for (1) hour.

Installation T-126 – 1100lbs per day

- 63 18 lb biscuits
- 2.5 lbs seed/ biscuit
- 335 gallons water/day
- 220V 30A

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Fodder unit is seeded and harvested every day

Fodder is fed using a feed wagon to mix with other supplements 1 time/day

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What we know about fodder/sprouts based on the literature

High (higher) in vitamins & minerals

(USDA National Nutrient Database Standard Reference V.1.3.1.)

- *100 g wheat sprouts = 2.6 mg Vitamin C; 0.225 mg Thiamin; 0.155 mg Riboflavin; 3.087 mg Niacin; 0.265 mg Vitamin B6; and 38 mcg Folate*

- *100 g wheat sprouts = 28 mg Ca; 82 mg Mg; 200 mg P; 169 mg K; 1.65 mg Zn*

What we know about fodder/sprouts

Converts starches to highly digestible sugars

(Food Science & Nutrition 28(5):401-437 1989)

- *May change feed conversion*
- *We don't know impact on rumen function*
- *May result in lowered incidence of acidosis (high starch diets)*

Free amino acid content increases – suggesting better protein utilization

(Food Chemistry 119:1195-1200 - 2010)

May reduce MUN's

What we know about sprouts/fodder

Sprouting legumes reduces alkaloids and improves the overall palatability and bioavailability of the nutrients

(Food Chemistry 117:599-602 2009)

- Also rich in plant secondary metabolites called phenolic compounds – anti-cancer – very potent antioxidants.

What we know about sprouts/fodder

Reduces phytic acid – will not tie up minerals to same degree as grains

(Food Chemistry 119:1195-1200 - 2010)

Dairy One

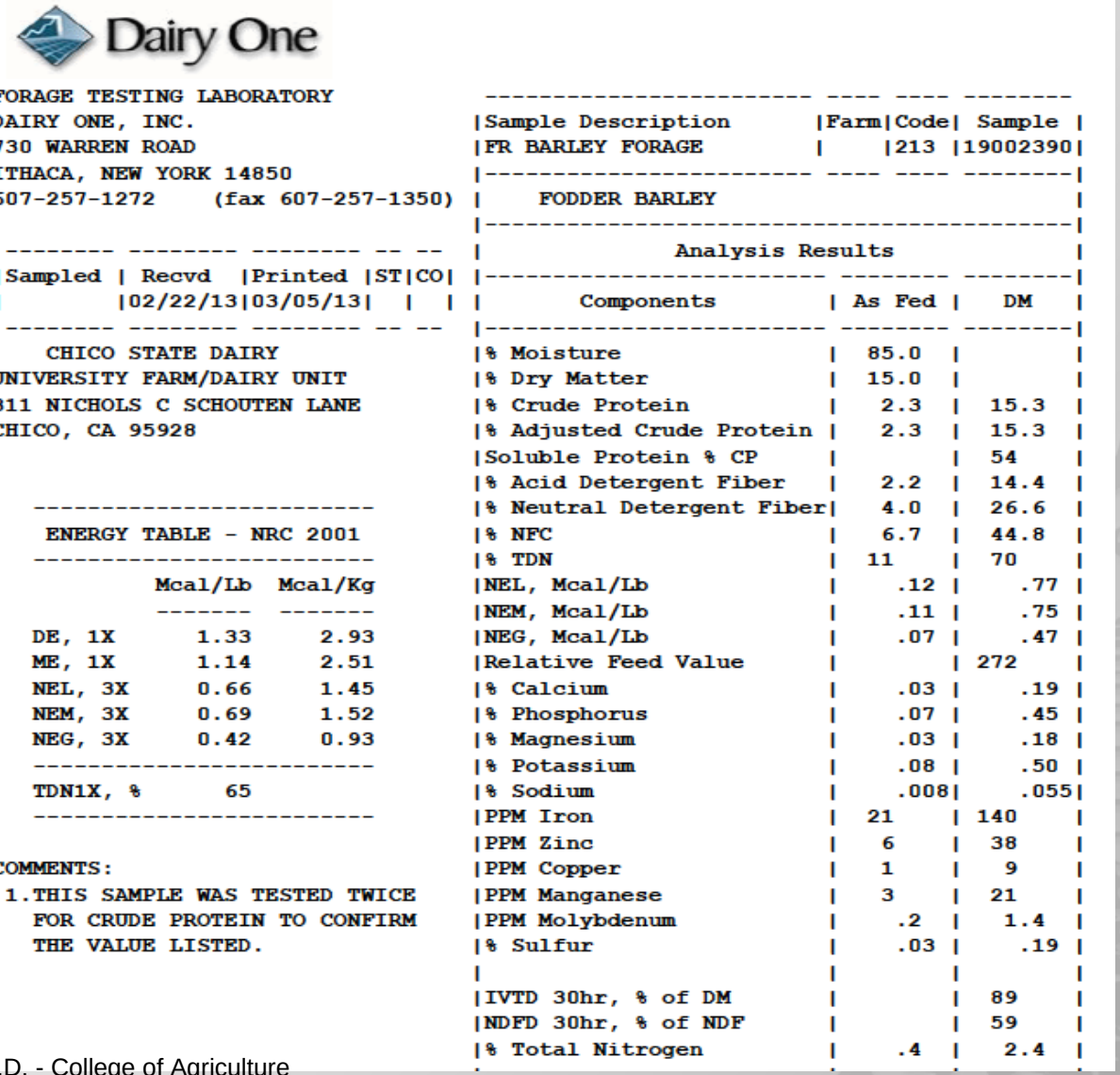
Fermentation Report

UNIVERSITY FARM/DAIRY UNIT
FODDER DAYS S N

Feed Type: MISC HAYLAGE
Statement ID: FODDER DAYS S N
Description:
Sample #: 19438690
Date: 07/30/2013

Component	DM Basis	Goal	Typical Value for DM Range < 24
Dry Matter, %	8.71		
Lactic Acid, %	7.10	> 3	3.34
Acetic Acid, %	1.52	< 3	4.02
Lactic/Acetic Ratio	4.68	2.0 - 3.0	0.80
Propionic Acid, %	0.12	< 1.0	0.72
Butyric Acid, %	0.13	< 0.1	1.60
IsoButyric, %	0.09		
Total Acids, %	8.96	5.0 - 10.0	9.70
pH, As sampled	3.60	< 5	5.03
Crude Protein, %	15.40		
Ammonia, CPE %	0.75		4.05
Amm-N, % of Total N	4.87	8.0 - 15.0	26.47

Fodder nutrient analysis



Dairy One

FORAGE TESTING LABORATORY
DAIRY ONE, INC.
730 WARREN ROAD
ITHACA, NEW YORK 14850
607-257-1272 (fax 607-257-1350)

Sampled	Recvd	Printed	ST	CO
	02/22/13	03/05/13		

CHICO STATE DAIRY
UNIVERSITY FARM/DAIRY UNIT
311 NICHOLS C SCHOUTEN LANE
CHICO, CA 95928

ENERGY TABLE - NRC 2001

	Mcal/Lb	Mcal/Kg
DE, 1X	1.33	2.93
ME, 1X	1.14	2.51
NEL, 3X	0.66	1.45
NEM, 3X	0.69	1.52
NEG, 3X	0.42	0.93
TDN1X, %	65	

COMMENTS:
1. THIS SAMPLE WAS TESTED TWICE FOR CRUDE PROTEIN TO CONFIRM THE VALUE LISTED.

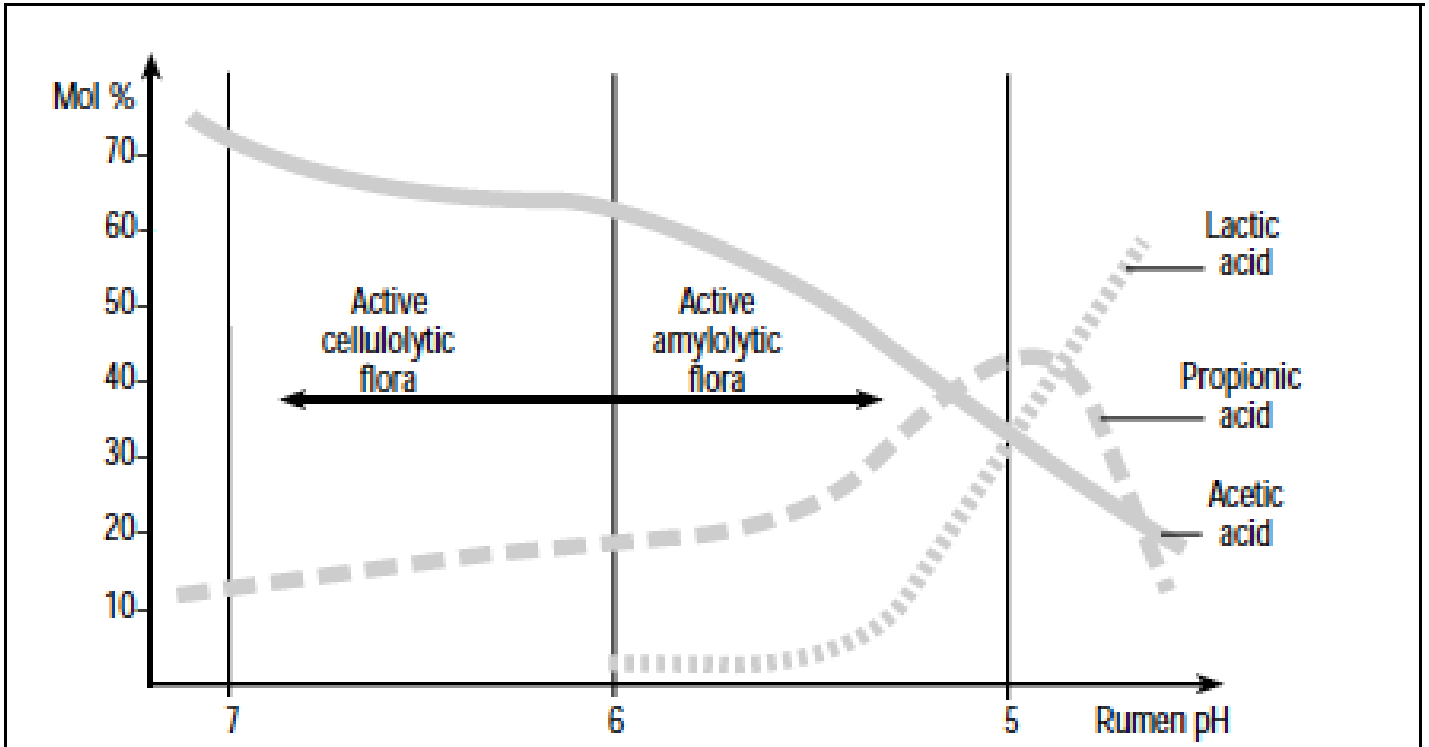
Sample Description	Farm	Code	Sample
FR BARLEY FORAGE		213	19002390
FODDER BARLEY			

Analysis Results

Components	As Fed	DM
% Moisture	85.0	
% Dry Matter	15.0	
% Crude Protein	2.3	15.3
% Adjusted Crude Protein	2.3	15.3
Soluble Protein % CP		54
% Acid Detergent Fiber	2.2	14.4
% Neutral Detergent Fiber	4.0	26.6
% NFC	6.7	44.8
% TDN	11	70
NEL, Mcal/Lb	.12	.77
NEM, Mcal/Lb	.11	.75
NEG, Mcal/Lb	.07	.47
Relative Feed Value		272
% Calcium	.03	.19
% Phosphorus	.07	.45
% Magnesium	.03	.18
% Potassium	.08	.50
% Sodium	.008	.055
PPM Iron	21	140
PPM Zinc	6	38
PPM Copper	1	9
PPM Manganese	3	21
PPM Molybdenum	.2	1.4
% Sulfur	.03	.19
IVTD 30hr, % of DM		89
NDFD 30hr, % of NDF		59
% Total Nitrogen	.4	2.4

Changes in rumen micro-flora with pH

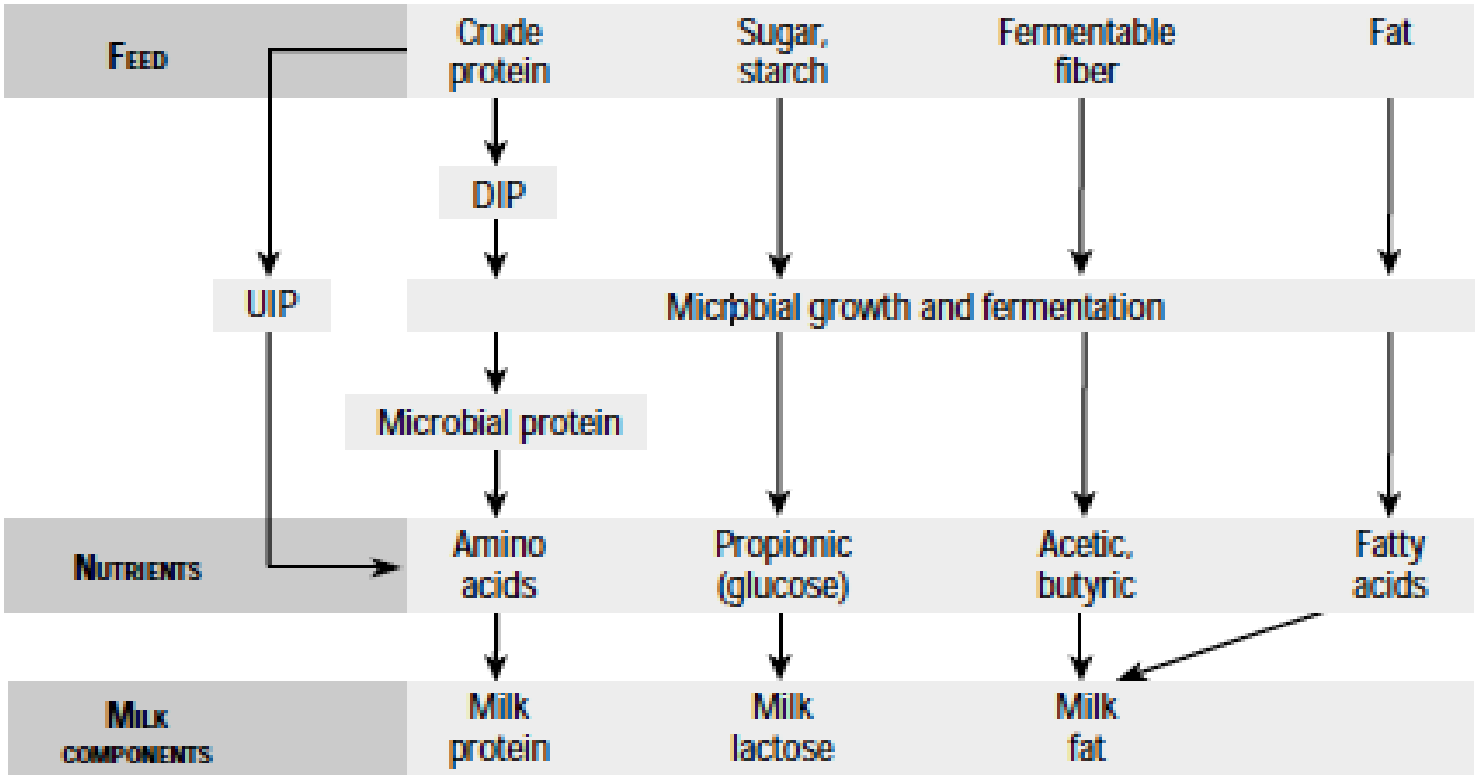
Figure 2. Ruminal fermentation as a consequence of adaptation due to pH regulation.



Kaufman, W., H. Hagemeister, and G. Durksen. Adaptation to changes in dietary composition level and frequency of feeding. In: Digestive Physiology and Metabolism in Ruminants, ed. Y. Ruckebusch and P. Thivend. Westport, Ct.: AVI Publishing, 1980, p. 587.

Microbes impact on milk components

Figure 3. Feed, nutrient flow from the rumen, and milk components.



Source: Sniffen, C. J. and H. H. Herdt. The Veterinary Clinics of North America: Food Animal Practice, Vol 7, No 2. Philadelphia, Pa.: W. B. Saunders, 1991.

Note: UIP = undegradable intake protein; DIP = degradable intake protein.

Differences among seed sources

Two different barley seed lots tested side by side

Seed	%Adj CP	SP % of CP	%ADF	%NDF	%NFC	%TDN	DM%	Nel	RFV	%N	ME
D6 Utah	20.3	70	24.9	47.3	26.6	60	7.6	0.60	137	3.2	1.09
D6 LW	15.3	54	14.4	26.6	44.8	70	15	0.77	272	2.4	1.32

Fodder Quality over Time on DM basis

	DM%	%CP	%Adj. CP	Soluable Protein as % of CP	Degradable P as % of CP	%NDICP	%ADF	%NDF	%NFC	% Starch	%TDN	Nel Mcal/lb	RFV	% total N	Metabolizable Energy Mcal/lb
Day 1	63.1	10.8	10.8	34	43	2.2	6.7	19.5	65.1	54.8	81	.86		1.7	
Day 2	44.4	11.1	11.1	50	59	1.8	8.4	17.3	67.5	50.3	82	.87		1.8	
Day 3	35.5	11.2	11.2	59	68	1.3	9.4	18.4	65.9	46.3	81	.86		1.8	
Day 4	20.8	11.4	11.4	65			9.8	21.1	56.9		68	.76	358	1.8	
Day 5	12.6	13.7	13.7	69			12.4	25.6	50.2		67	.73	288	2.2	

%CP increases
Soluble protein increases
Energy decreases

Day 1 – fresh seed

Day 2

Day 3

Day 4

Day 5

Day 6

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Experiment #1: Replacement Rates

Key Question: How many pounds of fodder does it take to replace a pound of grain?

Barley			**Grain**		
Seed Cost	$880/T	$0.44/lb	$617/T	$0.31/lb	$0.35/lb DM
lbs seed/brick	2.5		$/brick	$1.10	
lbs/brick	18		$/seed/d	$69.30	
# bricks /d	63		$ labor/d	$ 20.00	
lbs fodder/d	1134		$ utility/d	$ 5.00	
DM	15%		Total	$79.86	
			$/lb fodder	$0.06	
			$/lb DM	$0.27/lb DM	

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Experiment # 1: Replacement Rates

Treatments based on DM analysis

- 12 lbs of grain (as fed) n=15
- 6 lbs of grain (as fed) n=15
- 3 lbs of grain + 18 lbs of fodder (as fed) n=15
- 36 lbs of fodder (as fed) n=15

Dry matter analysis

Establishing equivalence on a DM basis

Feed Analysis	Nel DM basis	% DM	Treatments	DM Fed	Meg Calories
Parlor Grain mix	0.80	0.89	6 lbs grain	5.34	4.75
Fodder	0.77	0.15	36 lbs fodder	5.4	4.66

Exp.#1: Grain Replacement Study

Table 1. Means and standard deviations of milk production traits among the four treatments fed to CSUC organic dairy cows

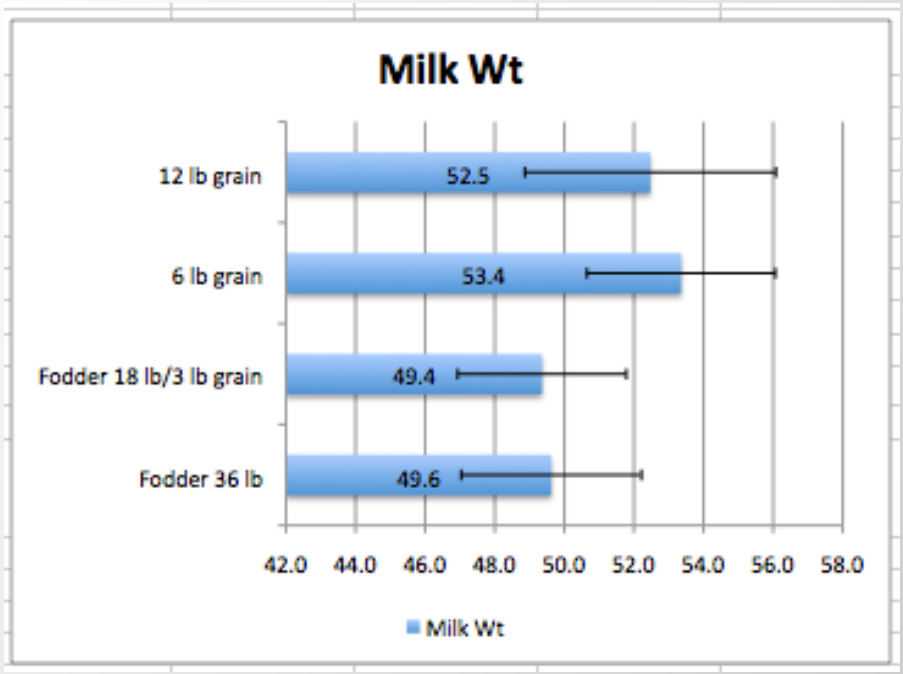
Treatment:	1: 12lb. Grain	2: 6lb. Grain	3: 3lb. Grain /18lb. B. Sprout	4: 36 lb. B. Sprout	P-Value
Variable: Milk Fluid*	49.6(6.70)	49.4(5.90)	53.4(7.30)	52.5(13.0)	**0.52**
% Protein	3.10(0.30)	3.10(0.30)	2.70(1.10)	3.20(0.20)	**0.15**
% Fat	3.90(0.30)	3.90(0.40)	3.70(1.00)	3.70(0.70)	**0.53**
% SNF	8.80(0.40)	8.80(0.30)	7.70(2.80)	9.00(0.30)	**0.07**
DIM	46.6(10.2)	48.5(7.00)	53.4(7.30)	52.5(13.0)	**0.24**
MUN	13.4(1.80)	14.2(2.10)	13.7(3.90)	14.7(3.10)	**0.76**

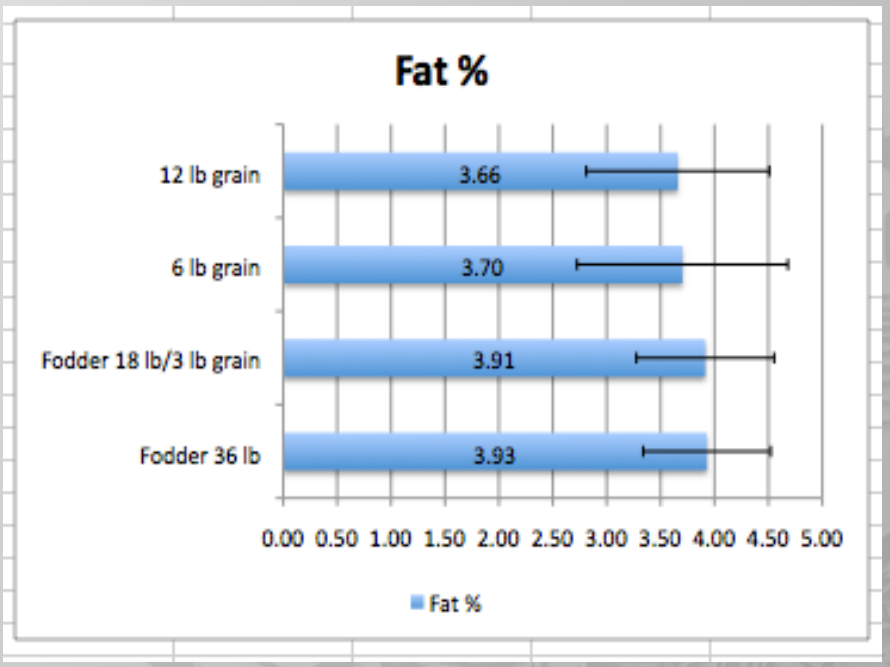
All numbers rounded up to 3 significant figures. Standard Deviation in parentheses

*Milk Fluid measured in pounds.

Experiment #1: Replacement Rates

Grain rations produced more milk/day on average (3 lbs) - although NS
Fodder rations produced more butter fat (0.4 % BF) – although NS





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Experiment #1: Replacement Rates

Milk pricing by component pricing ($2.09 BF; P; SNF)

12 lbs grain ration generated $17.30
6 lbs of grain generated $15.78
3 lbs grain & 18 lbs of fodder generated $16.33
36 lbs of fodder generated $16.45

Milk Pricing				$2.09			$2.09			$2.09	Total Revenue
Treatment	#'s/cow/d	% BF	Total lbs	$/day	% Protein	Total lbs	$/day	% SNF	Total lbs	$/day	Total $/day
12 lbs grain	52.5	3.66	1.92	$4.01	3.15	1.65	$3.45	8.96	4.70	$9.83	$17.30
6 lbs grain	53.4	3.70	1.98	$4.13	2.71	1.45	$3.02	7.74	4.13	$8.63	$15.78
3 lbs grain/18 lbs	49.4	3.91	1.93	$4.04	3.09	1.53	$3.19	8.82	4.35	$9.10	$16.33
36 lbs fodder - as	49.6	3.93	1.95	$4.08	3.11	1.54	$3.22	8.82	4.38	$9.15	$16.45

Experiment # 1: Replacement Rates

Feed Costs		$/lb		1# barley: 7#fodder Plus labor		
		$0.31		$0.06		
Feed Costs (As Fed)	Parlor Grain #'s	$ Parlor Grain $617/Ton	Fodder Grain #'s	$ Fodder grain $880/T	$ Supp. costs	Income over Supp Costs
12 lbs grain	12	$3.72			$3.72	$13.58
6 lbs grain	6	$1.86			$1.86	$13.92
3 lbs grain/18 lbs	3	$0.93	18	$1.08	$2.01	$14.32
36 lbs fodder - as fed			36	$2.16	$2.16	$14.29
	NeL/ # DM	% DM		DM Fed	MegaCal Fed	
Parlor Grain	0.80	0.89	6 lbs grain	5.34	4.7526	
Fodder	0.77	0.15	36 lbs fod	5.4	4.158	

Experiment #1: Replacement Rates

Income over feed costs IOFC

- 12 lbs of grain = $13.58
- 6 lbs of grain = $13.92
- 3 lbs grain/18 lbs fodder = $14.32
- 36 lbs fodder = $14.29

Highest to lowest IOFC

- 3lbs grain/18 lbs fodder
- 36 lbs fodder (zero grain)
- 6 lbs of grain
- 12 lbs of grain (I'm not making this up – I swear)

Experiment # 2 Fodder Milk Lipids

Question #2: What is the impact of fodder on milk lipids important to human health?

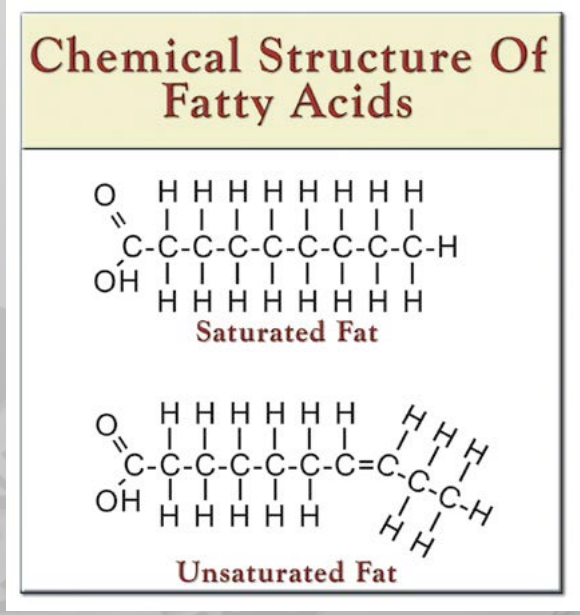
Treatments/Rations

- 12 lbs of grain
- 6 lbs of grain
- 3 lbs grain/18 lbs fodder
- 36 lbs fodder

Milk Sampling Crew

Experiment # 2 Fodder Milk Lipids

Saturated Fats: reportedly hard on your heart and vascular system – particularly the shorter chain SFA such as C14:0 (myristic); C16:0 (palmitic) because they elevate blood LDL.



Overall - No difference in Total SFA content between treatments

However…. Fodder consistently reduced the shorter chain SFA concentrations (C5:0; C7:0; C8:0; C9:0; C10:0; C11:0; C12:0; C13:0 and C14:0) responsible for elevating serum LDL

Experiment # 2 Fodder Milk Lipids

Omega 6 & Omega 3 and the n6:n3 ratio

Elevated intake of Omega 3 reduces CVD; Type 2 Diabetes; Hypertension; Cancer; Dementia

Omega 6 causes inflammation

Fodder elevates DHA (C22:6 n-3)
Grain elevates n-6 (not good)

Fodder has a healthier n-6:n-3 ratio

Experiment #3: In-Situ Digestibility

Question: What is the impact of fodder on the rumen – and how does it impact feed digestibility?

In-Situ digestibility experimentation provides feed degradation rates under different rumen conditions

We created two rumen environments:

1) Grain diet (6 lbs grain plus alfalfa)
2) Fodder diet (18 lbs fodder plus alfalfa)

2 lbs of fodder for every 1 lb of grain

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Experiment #3 In-Situ Digestibility

5 gram samples of dried/ground feed were deposited in the rumen

Feed tested included:
Alfalfa
Corn
Fodder

Samples were removed at various time points to determine how much feed had been degraded:

Time points included: 96 hrs; 72 hrs; 48 hrs; 36 hrs; 24 hrs; 16 hrs; 12 hrs; 8 hrs; 6 hrs; 4 hrs and 2 hrs

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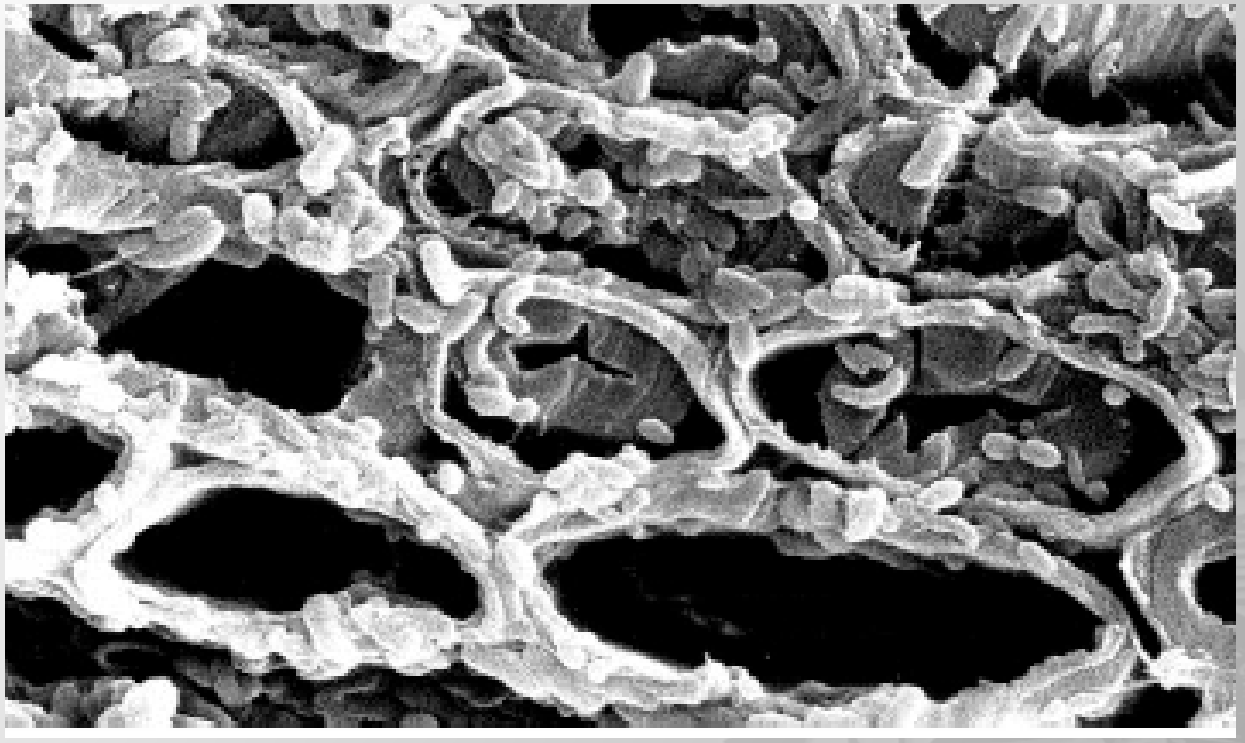
Rumen micro-flora digesting fibrous materials



Rumen bacteria attached to alfalfa stem tissues during digestion as observed by scanning electron microscopy.

Jung et al., USDA-ARS/University of Minnesota
http://oca.cce.umn.edu/ltu_portfolio/example/ag/pdfs/jung.pdf

Rumen Fluid Collection Crew

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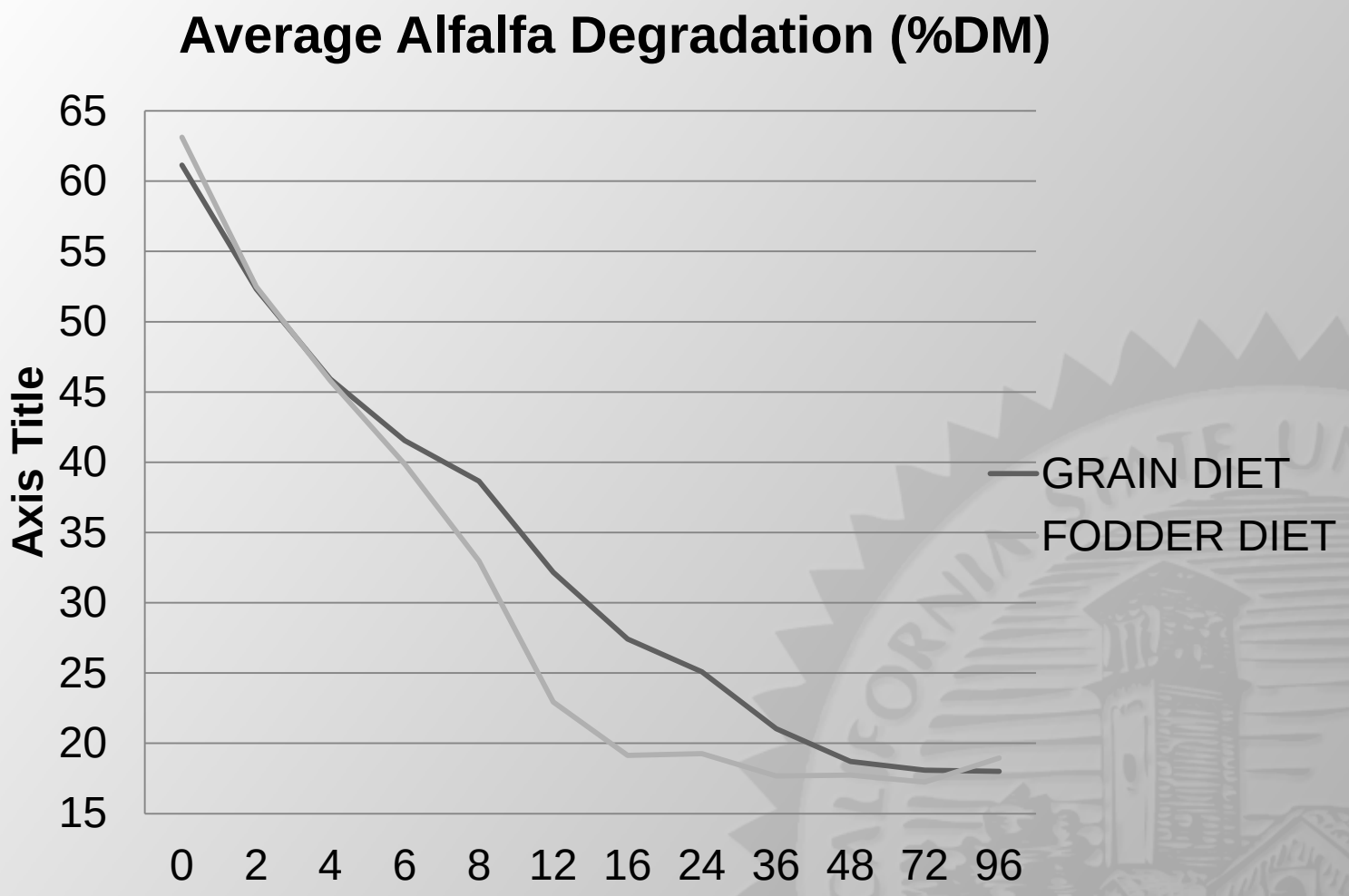
Preliminary Alfalfa Degradation Rates



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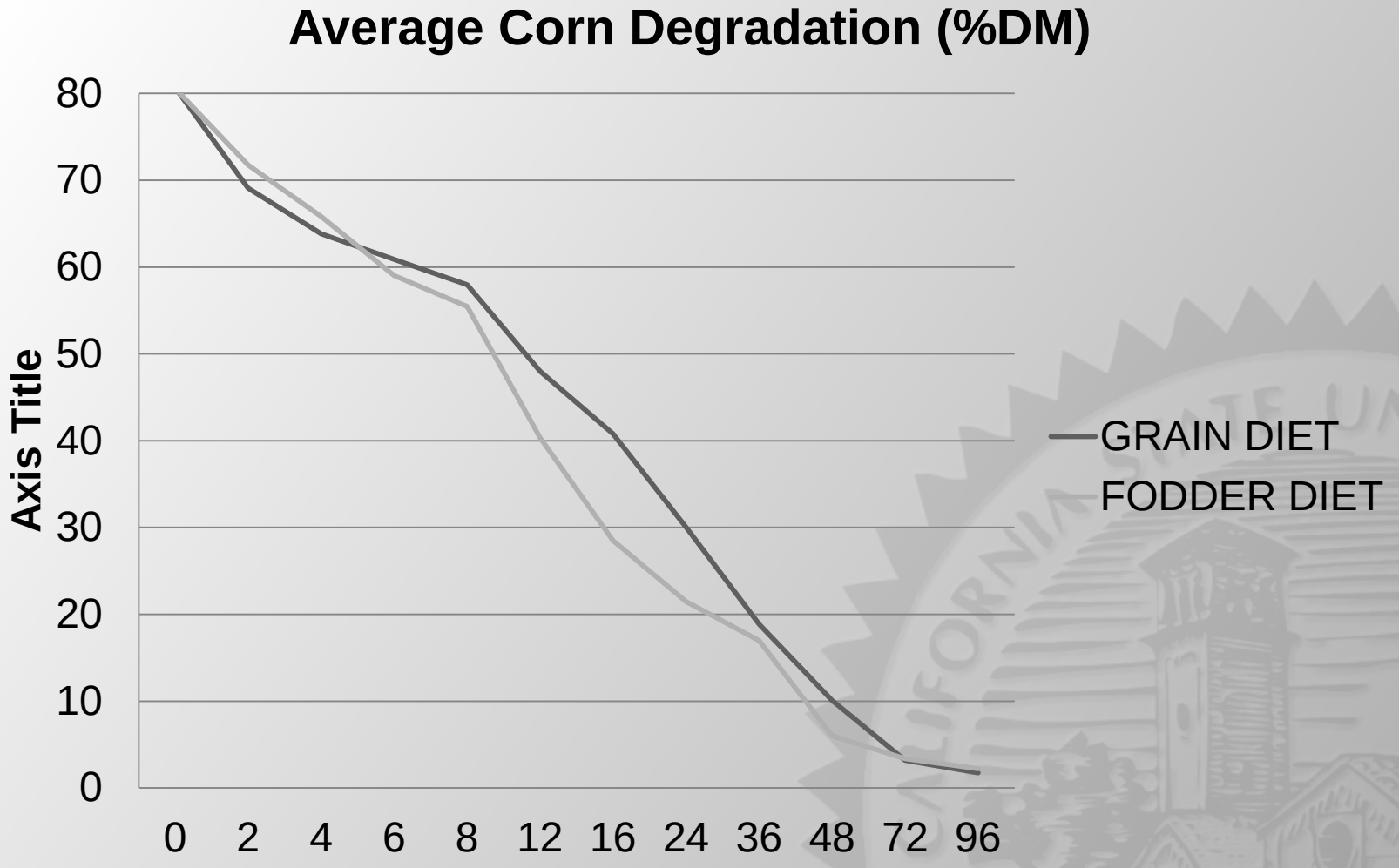
Preliminary Corn Degradation Rates



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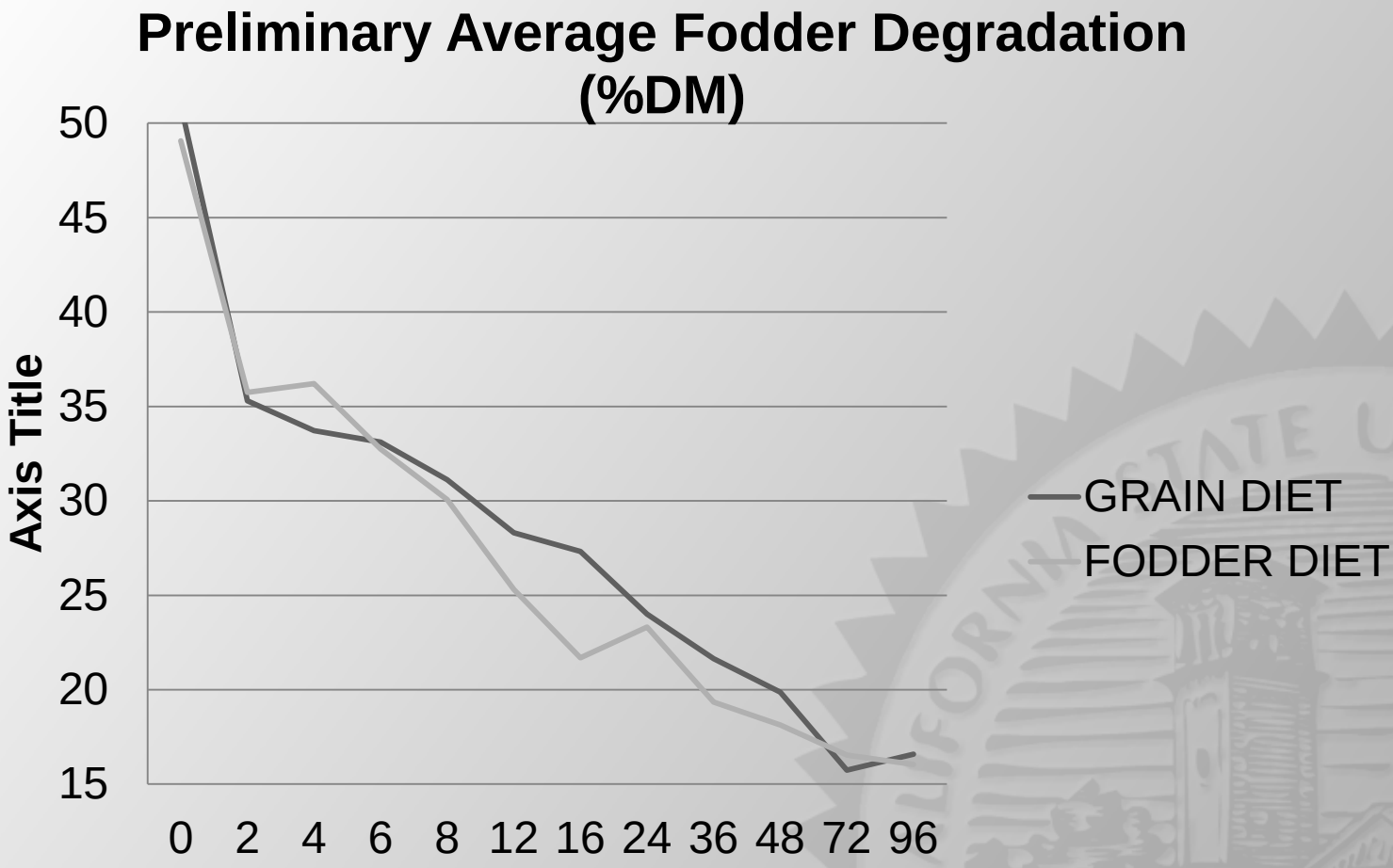
Preliminary Fodder Degradation Rates



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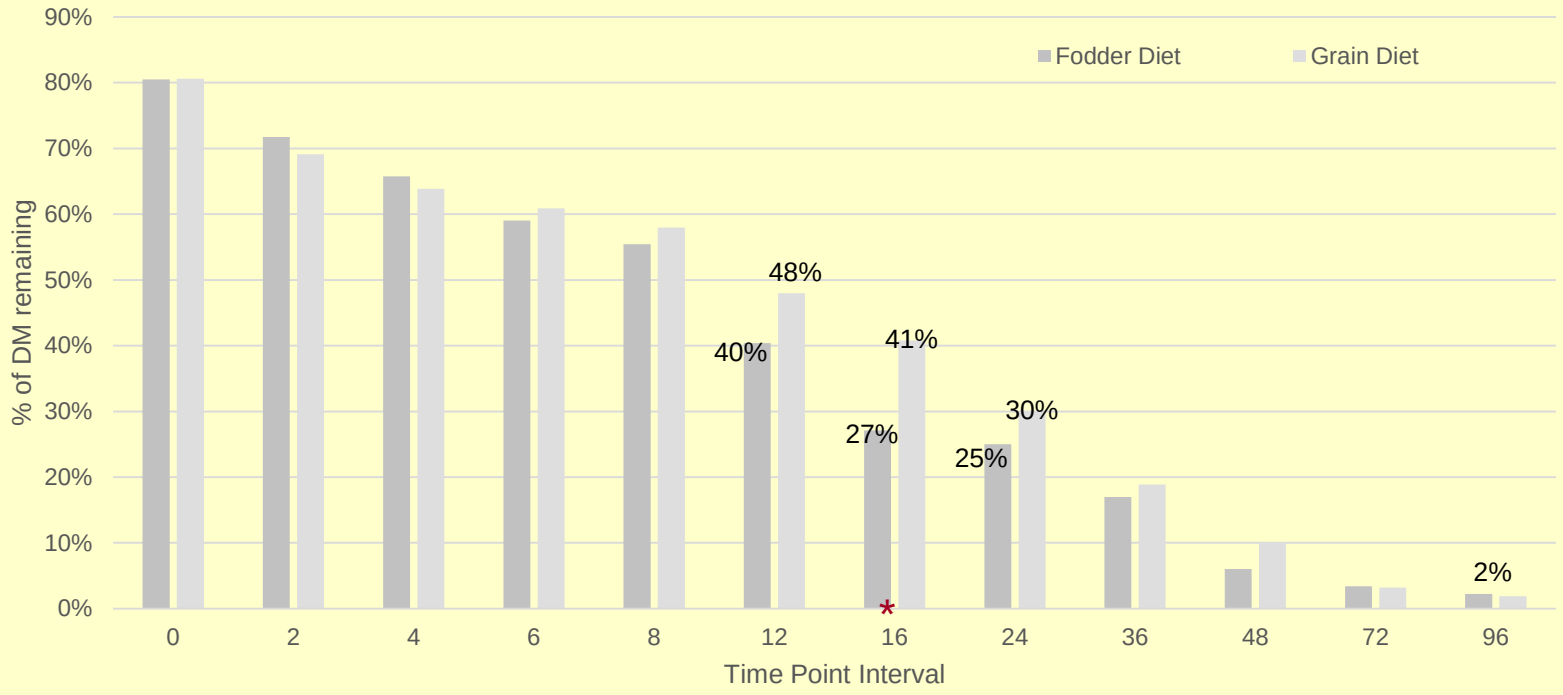
Preliminary Data

In-Situ Degradation: Average Corn DM Residual (%)



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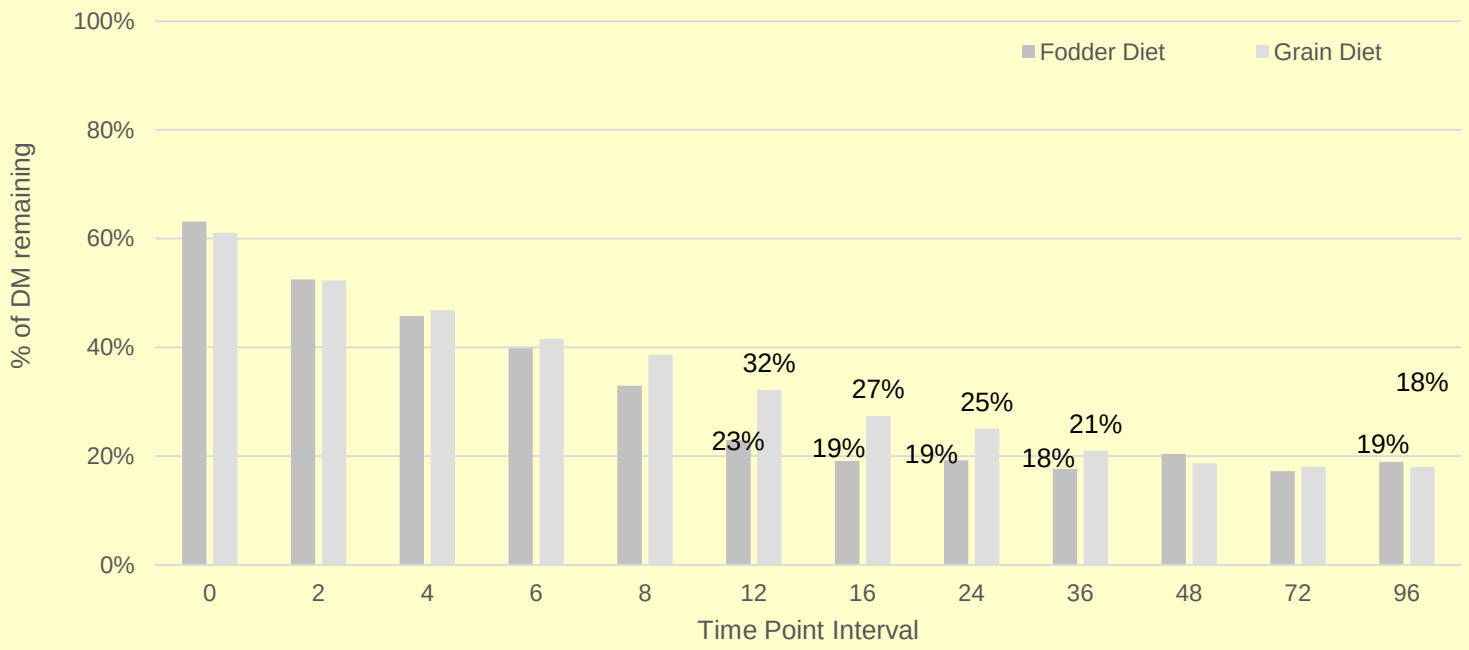
Preliminary Data

In-Situ Degradation: Average Alfalfa DM Residual (%)



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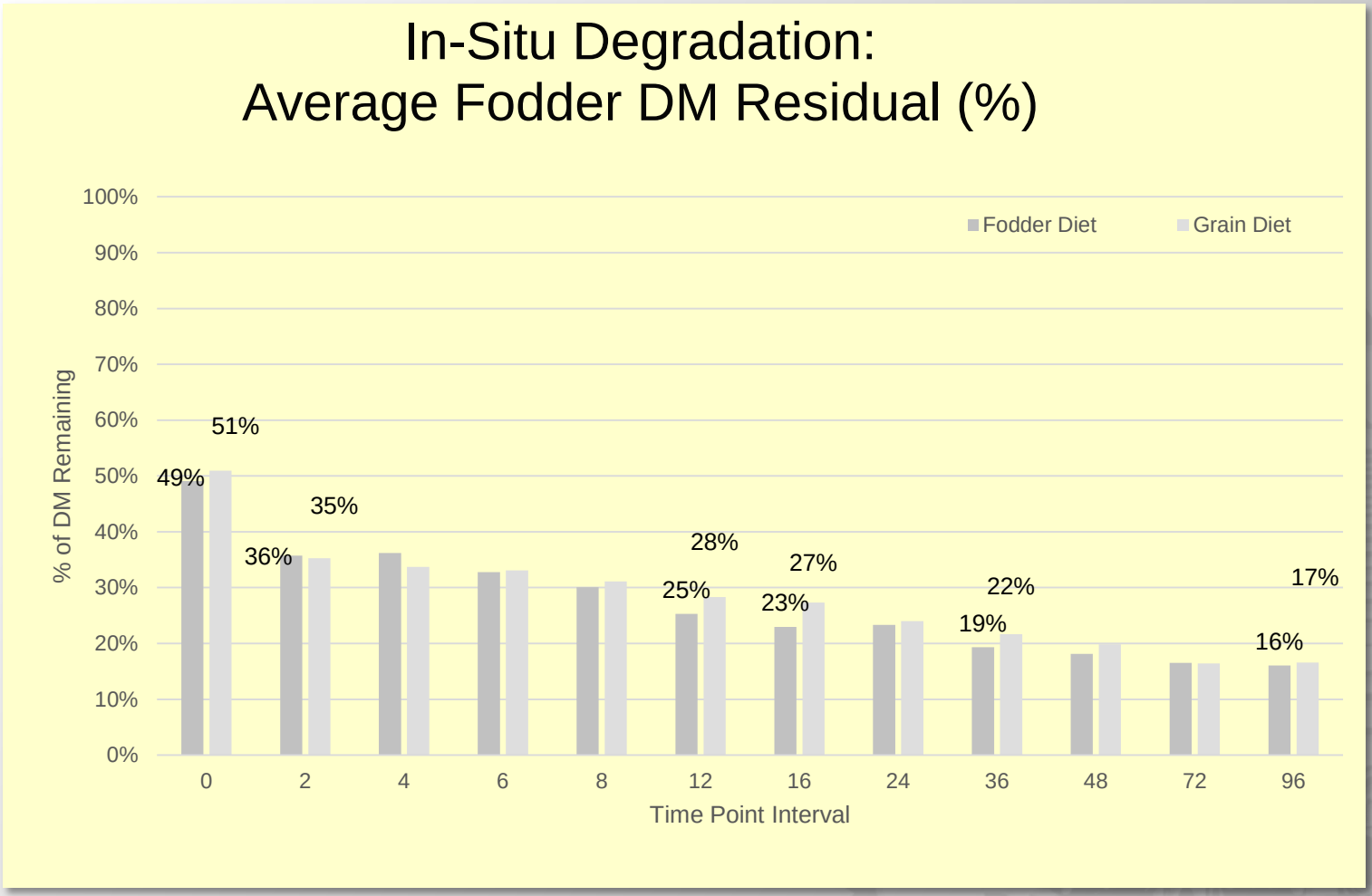
Preliminary Data



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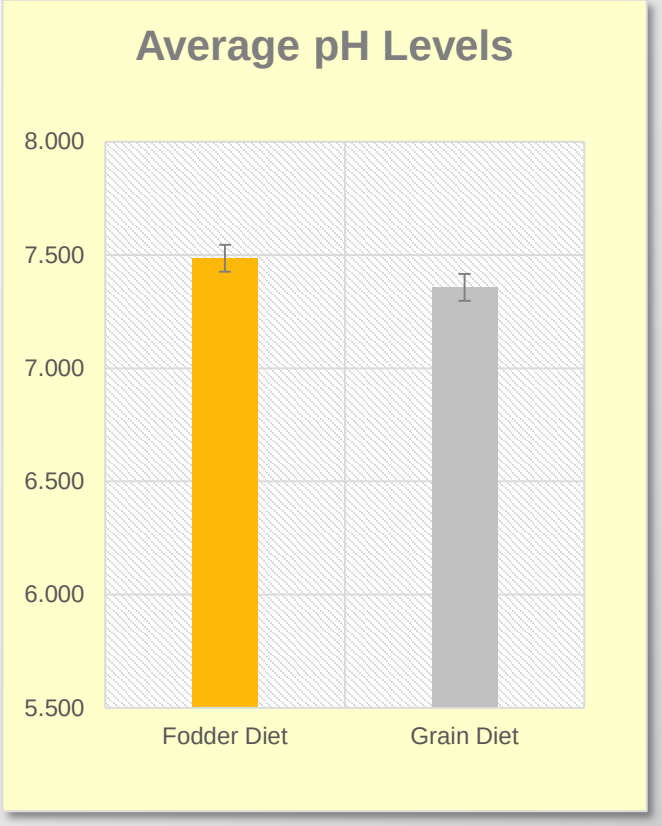
Rumen Fluid Extraction Results: pH Measurements



Average pH Levels Per Diet:

Grain	*7.356*	*Standard Error*	*0.059*
Fodder	*7.485*	*Standard Error*	*0.057*

Analysis of Variance P-Value *0.124*

- *No Statistical Difference*

Sprouted grain (fodder) has a pH of 5.0

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Hypothesis:

Sprouted grains may break down quickly in the rumen making additional energy available for rumen microbial replication and digestion; thus improving the rate of degradation of all feeds (both fiber and starch).

In-Situ Implications

Feeding sprouted grains improves the efficiency of feed degradation at the12, 14 and 16 hr time point

Faster feed degradation rates would suggest a higher throughput - and may therefore represent more total milk production due to higher feed intakes over time.

Funding

- California Agriculture Research Institute
- Curt Chittock with Simply Country, Grass Valley, CA

Installation Afi Milking System

- Daily milk weights
- Pedometers – monitor heat activity/health in real time
- Daily somatic cell readings

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Students and Staff that make this possible

2014 DMT at WODPA

Conclusions

- Rumen dynamics change under the influence of fodder and do not appear to hold to the 6:1 conversion as implied by the DM analysis.
- Comparable milk production was established with a 2 lbs of fodder to 1 lb of grain exchange.
- Fodder improves the milk lipid profile by reducing LDL enhancing short chain SFA; enhancing DHA n-3 concentration and reducing the amount of n-6 (more favorable n-6:n-3 ratio).
- Adding fodder to the ration at a rate of 18 lbs/day enhances feed degradation rates of both fiber and starch-based feeds.
- Fodder based rations had a higher IOFC than the grain-based rations

Caveats

- Fodder production can be difficult
  - *Systems vary widely and can be very costly*
    - *Need to fully assess the ROI*
  - *There is considerable labor associated with most systems*
  - *Requires a high degree of persistence*
  - *Mold is a continual problem - we had a lot of down time*
  - *Training is necessary*
  - *Can be a long learning curve*
  - *There can be a lot of maintenance associated with the system*

Thank you - Questions

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