Feed GrainV2.0
Background and Development Guide

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Introduction: Management practices, such as grinding, (Remond et al., 2004; Theurer, 1986), steam flaking (Callison et al., 2001), ensiling (Oba and Allen, 2002), or type of endosperm (Lopes et al., 2009; Allen et al., 2008), have been demonstrated to alter starch digestion and lactation performance of dairy cows. Despite knowledge (Firkins et al., 2001) of factors that influence feed grain utilization by dairy cows, dairy educators, nutrition consultants and feed and forage testing laboratories, have been challenged to apply an integrated approach to feed grain evaluation. Previously, Feed GrainV1.0 was developed and provided a basic evaluation system for feed grains integrating physical characteristics and nutrient composition of the grain. Recent research at the University of Wisconsin-Madison and other universities has provided new insights into feed grain utilization by dairy cattle. As a result of new research, Feed GrainV2.0 has been developed to improve upon the basic concepts of Feed GrainV1.0. Feed GrainV2.0 incorporates new research concepts into an integrated approach of feed grain evaluation for lactating dairy cows.

Objective: To provide an educational platform for dairy educators, consultants and producers to evaluate feed grains for the principal components which influence feed grain digestion and dairy cattle performance.

Dry vs High Moisture Corn is Redefined: In Feed GrainV2.0 dry and high moisture corns are redefined as unfermented and fermented corns using the concentration of ammonia (NH_3-N) in corn as a benchmark nutrient. Feed GrainV2.0 employs NH_3-N to define corn as unfermented or fermented for the following reasons. First, dry corn or freshly harvested corn > 15 % moisture does not contain any appreciable amount of NH_3-N. Therefore when corn is devoid of NH_3-N there is a high probability the corn is not fermented. Using NH_3-N as a benchmark of fermentation removes the confusion whether transitional corns containing low moisture (18.0-24.0 %) feed like dry corn or high moisture corn. Likewise, using NH_3-N as a benchmark of fermentation removes the confusion of whether a high moisture corn at harvest or fermented a few days' feeds like dry or high moisture corn. Second, recent research has demonstrated that NH_3-N helps define the intensity and duration of high moisture corns during the ensiling process. Because the NH_3-N concentration in high moisture corn increases due to the intensity and length of fermentation the effects of ensiling time and intensity of fermentation on starch digestibility are accounted for in Feed GrainV2.0. Finally, because NH_3-N concentrations in high moisture are relatively easy to determine with near infrared reflectance spectroscopy (NIRS) defining corn types, intensity and length of fermentation is rapid and economical.

Required Laboratory Measurements

Item	Abbreviation	Units	Method	Note
Dry Matter	DM	% as fed	Chemistry	
Mean Particle Size	MPS	microns	ASAE, 2008	
Starch		% of DM	NIRS or Chemistry	
Crude Protein	CP	% of DM	NIRS or Chemistry	
NH_3-N		% of CP[1]	NIRS or Chemistry	
Prolamin Protein		% of DM	Larson and Hoffman, 2008	Unfermented corn
Neutral Detergent Fiber	aNDF	% of DM	NIRS or Chemistry	
Ash		% of DM	NIRS or Chemistry	
Fat		% of DM	NIRS or Chemistry	

1 Or as % of total N.

Common Range of Feed Grain[1] Inputs:

Item	Abbreviation	Units	Low	Average	High
Dry Matter	DM	% as fed	<65	75	>85
Mean Particle Size	MPS	microns	<750	1500	>2250
Starch		% of DM	<65	69	>73
Crude Protein	CP	% of DM	<8.0	9.0	>10.0
NH_3-N		% of CP[2]	0.0	3.0	>6.0
Prolamin Protein		% of DM	<3.4	3.9	>4.4
Neutral Detergent Fiber	aNDF	% of DM	<7.0	9.0	>11
Ash		% of DM	<1.3	1.7	>2.1
Fat		% of DM	<3.5	4.0	>4.5

1 Values for dry and high moisture corns.

2 Or as % of total N.

Feed GrainV2.0 Outputs:

Item	Abbr.	Units	Low	Average	High
Moisture		% as fed	<15	25	>35
Effective Mean Particle Size[1]	eMPS	microns	<600	1200	>2400
Starch Fermentation Rate (As Fed)[2]	kd	% /hour	<13	18	>23
Ruminal Starch Digestibility	RSD	% of starch	<50	60	>70.0
Starch Digestibility (Total Tract)	TTSD	% of starch	<89	92	>95
Non Fiber Carbohydrate	NFC	% of DM	<77	80	>83
Non-starch NFC		% of DM	<8.0	9.0	>10
Total Digestible Nutrients, 1X	TDN	% of DM	<86.5	87.5	>89.0
Net Energy Lactation, 3X	NE_L	Mcals/lb	<0.86	0.88	>0.92
Net Energy Maintenance	NE_M	Mcals/lb	<0.93	0.95	>0.97
Net Energy Gain	NE_G	Mcals/lb	<0.63	0.65	>0.67
Metabolizable Energy, 3X	ME	Mcals/lb	<1.35	1.37	>1.40
Relative Grain Quality	RGQ		<130	150	>170

1 Starch within particles is estimated to effectively ferment at this comparative dry corn mean particle size.
2 Estimated ruminal starch fermentation rate of the grain in its original form as fed to dairy cattle. Translated from in vitro gas production rates of un-dried, un-ground dry and high moisture corns to ruminal passage rates of 16.0 and 12.0 %/h for unfermented and fermented corns, respectively.

Feed GrainV2.0 Calculations: Calculations within Feed GrainV2.0 employ a mechanistic model with physical and nutritional chemistries of corns required for calculations. Feed Grain V2.0 does not require measures of in vitro starch digestibility or in vitro gas production of feed grains. The following basic steps are used in Feed GrainV2.0 to calculate the outputs described above. A complete view of all calculations of Feed GrainV2.0 are detailed within the operational program which is available at http://www.uwex.edu/ces/dairynutrition/

- Feed grains are dried and mean particle size (MPS) is determined using ASAE, 2008 methods.
- The ammonia nitrogen (NH_3-N) concentration of feed grains is determined. Because dry and fresh corns are largely devoid of ammonia nitrogen corns with <0.50 % of NH_3-N, % of total N) are classified as unfermented. Corns with NH_3-N concentrations >0.50 are classified as fermented.
- The prolamin concentration of unfermented feed grains is determined.
- The prolamin concentration in unfermented feed grains is used to adjust MPS to effective MPS (eMPS). The MPS of unfermented feed grains with greater prolamin concentrations are considered to be more effective at resisting bacterial digestion of starch and as a result eMPS maybe > than MPS. Conversely, unfermented feed grains with lesser prolamin concentrations are considered to be less effective at resisting bacterial digestion of starch and as a result eMPS maybe < than MPS.
- The ammonia (NH_3-N**)** concentration in fermented feed grains is used to adjust MPS to effective MPS (eMPS). The MPS of fermented feed grains with lesser NH_3-N concentrations are considered to be equally or marginally less effective at resisting bacterial digestion of starch and as a result eMPS maybe =< MPS. Conversely, fermented feed grains with greater NH_3-N concentrations are less effective at resisting bacterial digestion of starch and as a result eMPS will be < than MPS.
- A fractional rate of starch digestion is estimated from eMPS.
- Post ruminal flow of starch is estimated assuming feed grain passage rates of 16.0 and 12.0 %/h for unfermented and fermented corns, respectively.
- Ruminal starch digestibility is calculated by difference (100-Post ruminal starch flow).
- Post ruminal starch digestibility is estimated assuming surface area of particles presented post-ruminally is positively related to starch hydrolysis potential.
- Total tract starch digestibility (TTSD) is estimated as the sum of ruminal starch digestibility plus net post-ruminal digestibility.
- Estimated TTSD is used as the digestion coefficient for starch in a summative equation.
- Energy values for feed grains are calculated using a summative equation (NRC, 2001) with independent digestion coefficients for starch and non-starch non-fiber carbohydrates.
- A relative grain quality index is calculated from total tract starch digestibility.

Validation: Feed GrainV2.0 was validated using published research trials involving lactating dairy cows as a guide. Feed grainV2.0 was not evaluated for and is not intended for use for growing beef cattle, cereal grains or steam flaked corns. The validation of Feed GrainV2.0 required some flexibility in research literature interpretation because of a lack or absence of physical and chemical measurement continuity in the literature. Placing more rigid trial criteria into the validation process would have been desirable but would have resulted in a very limited data base to conduct a validation. In general, trials used to validate Feed GrainV2.0 fed > 80 %

of starch from grain, reported MPS, made direct comparisons of grain type and reported in vivo TTSD. Most trials did not report prolamin values and a value of 3.9% of DM was used for all trials involving unfermented corn unless otherwise defined. An average NH_3-N concentration of 4.0 % was used for all trials involving fermented corn. In vivo TT SD for unfermented corns were adjusted for random study effects (St-Pierre, N.R., JDS:84-741-755) but insufficient data was available for fermented feeds and TT SD were adjusted for an average MPS slope effect. Finally, in some trials non-structural carbohydrate digestibility had to be used as a surrogate for TTSD.

Capstone literature used to establish relationships between observed and predicted in vivo ruminal and total tract starch digestibility for Feed Grain V2.0. [1,2]

Author(s)	Citation	Grain Type	Processing	Moisture	MPS,um	Prolamin, % DM[3]	NH_3-N, % of N[4]	In vivo TT SD	Ruminal SD	In vivo TTSD (Study adj)[5]	Feed Grain V2.0 Predicted TT SD	Feed Grain V2.0 Predicted Ruminal SD
Eastridge et al.*	2011 J. Dairy Sci. 94:3045-3053	Dry	Ground	15	800	3.9	.	96.3	.	94.6	93.8	.
		Dry	Ground	15	1900	3.9	.	94.1	.	91.4	90.0	.
Reis et al.	2001 J. Dairy Sci. 84:429–441	HMC	Ground	24.7	2220	.	4.0	92.4	.	93.0	92.0	.
		HMC	Rolled	24.7	3140	.	4.0	87.2	.	91.1	91.6	.
San Emeterio et al.	2000 J. Dairy Sci. 83:2839–2848	HMC	Rolled	30.0	4430	.	4.0	85.5	.	88.4	89.2	.
		HMC	Ground	30.0	1320	.	4.0	90.2	.	94.9	95.3	.
		HMC	Rolled	30.9	3780	.	4.0	84.1	.	89.7	90.4	.
		HMC	Ground	30.9	1020	.	4.0	91.8	.	95.5	96.0	.
		Dry	Ground	15	3280	3.9	.	80.4	.	84.3	85.3	.
		Dry	Ground	15	1110	3.9	.	88.1	.	90.0	92.6	.
Callison et al[6]	2001 J. Dairy Sci. 84:1458–1467	Dry	Fine Grind	15	1200	3.9	.	98.0	.	93.6	92.3	.
		Dry	Medium Grind	15	2600	3.9	.	92.2	.	85.8	87.7	.
		Dry	Coarse Grind	15	4800	3.9	.	91.3	.	81.9	80.1	.
Dhiman et al.	2002 J. Dairy Sci. 85:217–226	Dry	Fine Grind	15	1130	3.9	.	96.1	.	94.3	92.6	.
		Dry	Coarse Grind	15	1650	3.9	.	93.6	.	91.4	90.8	.
Knowlton et al.	1996 J. Dairy Sci. 79:5574€4	Dry	Ground	15	827	3.9	.	92.2	.	92.3	93.7	.
		Dry	Cracked	15	3265	3.9	.	85.6	.	87.2	85.3	.
		Dry	Ground	15	1250	3.9	.	87.3	.	87.7	92.2	.
Yu et al.	1998 J. Dairy Sci. 81:777–783	Dry	Rolled	15	1180	3.9	.	95.8	.	95.3	92.4	.
		Dry	Rolled	15	2450	3.9	.	87.4	.	86.4	88.2	.
Lopes et al.	2009 J. Dairy Sci. 92:4541-4548	Dry	Rolled	15	1792	7.5	.	89.6	.	87.5	87.1	.
		Dry	Rolled	15	1394	2.8	.	95.1	.	93.3	92.5	.
		Dry	Rolled	15	1456	1.7	.	96.6	.	94.8	93.3	.
Krause and Combs*	2003 J. Dairy Sci. 86:1382-1397	Dry	Rolled	15	3200	3.9	.	88.2	.	86.0	85.4	.
		HMC	Rolled	26.9	3900	.	4.0	93.4	.	89.5	92.3	.
Krause et al.[7]	2003 J. Dairy Sci. 86:1341-1353	Dry	Ground	15	682	3.9	.	92.4	.	94.7	94.2	.
		Dry	Ground	15	1292	3.9	.	86.4	.	89.6	92.0	.
		Dry	Ground	15	1017	3.9	.	90.2	.	93.0	92.9	.
		Dry	Ground	15	1540	3.9	.	85.1	.	88.6	91.1	.
Ekinci and Broderick	1997 J. Dairy Sci. 80:3298–3307	HMC	Rolled	32.0	4330	.	4.0	94.2	.	88.6	89.2	.
		HMC	Ground	32.0	1660	.	4.0	98.8	.	94.2	94.5	.
Krause et al.*	2002 J. Dairy Sci. 85:1936-1946	Dry	Ground	15	1550	3.9	.	93.1	.	92.1	91.1	.
		HMC	Ground	25.8	1600	.	4.0	97.4	.	94.3	94.6	.
Knowlton et al.	1998 J. Dairy Sci. 81:1972–1984	HMC	Ground	30.0	489	.	4.0	98.2	86.8	96.6	97.5	80.0
		HMC	Rolled	30.0	1789	.	4.0	95.7	81.2	93.9	94.2	62.5
		Dry	Ground	15	618	3.9	.	88.9	60.9	93.3	94.4	59.8
		Dry	Rolled	15	1725	3.9	.	76.4	69.2	83.6	90.6	47.4
Remond et al.[8]	2004 J. Dairy Sci. 87:1389–1399	Dry	Ground	15	730	5.0	.	91.4	58.6	93.7	93.6	56.4
		Dry	Ground	15	1800	5.0	.	86.0	49.8	88.6	89.3	44.7
Oba and Allen*	2003 J. Dairy Sci. 86:184-194.	Dry	Ground	15	880	3.9	.	93.6	46.4	93.5	93.5	56.0
		HMC	Ground	36.7	1860	.	4.0	94.6	64.8	93.7	94.1	62.0
Taylor and Allen[9]*	2005 J. Dairy Sci. 88:1425-1433	Dry	Ground	15	1594	5.0	.	91.7	34.9	89.9	90.1	46.4
		Dry	Ground	15	1377	2.0	.	96.3	57.0	94.7	93.1	54.7

[1] HMC=high moisture corn, MPS=mean particle size, TT=total tract, SD=starch digestibility, DM= dry matter, CP= crude protein.

[2] Trial Criteria 1) > 80 % of starch from grain, 2) MPS reported, 3)direct comparsion grain type, 4) in vivo TT SD measured.

[3] An average prolamin value of 3.5% of DM was used for all trials involving unfermented corn unless otherwise defined.

[4] An average soluble crude protein value of 45 % was used for all trials involving fermented corn.

[5] In vivo total tract starch digestibilities were adjusted for random study effects (St-Pierre, N.R., JDS:84-741-755)

[6] Non structural carbohydrate digestibility was used as a surrogate for TTSD.

[7] Pure starch was added to reduce MPS.

[8] Inclusion of all treatments in experiments resulted in failure of mixed statistical models to coverge suggesting outlier in vivo data.

Prolamin values of 5.0 % of DM utilized as the trial indicated semi-flint corns were fed.

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