Measuring DM and NDF Digestibility and Defining Their Importance

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Why do we measure digestibility

¥ Digestibility is important because feces represent the greatest loss of ingested energy

—Feces = 20-50% loss of energy (DE)

—Gasses + Urine = 15-25% loss of energy (ME)

—Heat = 5-15% loss of energy (NE)

¥ Uses (value) of measuring digestibility

—As an indicator of feed nutritive value

—As a predictor of animal performance

Digestibility as a Measure of Animal Performance

¥ Want to maximize the accuracy of measuring animal performance

—Lab results must mimic field performance

—Animal and diet must match field conditions

¥ Animal differences are an integral part of the measurement

—Performance is determined by both feed and animal characteristics

—Want to duplicate actual performance

Digestibility as a Measure of Animal Performance

¥ In vivo production digestibility protocol

- —Performance status of animals
- —Production level of intake (1-5X Mnt)
- —Ad libitum (free choice) intake with refusals = selection
- —Measures digestibility during production
- —Much greater variability = difficult to measure inputs and outputs

Digestibility as a Measure of Feed Nutritive Value

¥ Want to maximize the accuracy and precision of measuring feed s nutritive value

—Must be repeatable within labs

—Must be reproducible among labs

¥ Must minimize animal differences (within and among labs)

—Animals are the measuring device

—Want to measure feed, not animal differences

Digestibility as a Measure of Feed Nutritive Value

¥ Standardized in vivo digestibility protocol

- Mature animals
- Maintenance level of intake (1X Mnt)
- No selection or refusals
- Measures maximum digestibility
- Weigh feed, refusals and feces for 5-7 days

In Vivo Digestibility

¥ Is a biological evaluation of a feed

¥ Is not a constant, but varies with

- –Species
- –Size
- –Production level
- –Intake
- –Selection and sorting
- –Methodology

In Situ / In Sacco Digestibility

¥ Is a biological evaluation of a feed

¥ Feed is sealed in a porous bag and suspended in the rumen of fistulated cows

¥ Assume in situ = in vivo

- —But only measures fermentative digestion
  - ¥ Not adequate for low fiber feeds
  - ¥ Losses from the bag may compensate for the lack of intestinal digestion

In Situ / In Sacco Digestibility

- ¥ Apparent value is in mimicking ruminal digestion for production levels and diets
- ¥ More difficult to standardize, especially among labs when used for feed evaluation
  - —Bag dimensions and pore sizes
  - —Washing of bags and removal of fines
  - —Cyclic and variable ruminal conditions
  - —Variability among animals

In Vitro Digestibility

¥ Single-stage IVDMD

—Incubate ruminal fluid with feed in buffer

—Dry residues and weigh

¥ Two-stage Tilley & Terry IVDMD

—Incubate ruminal fluid with feed in buffer

—Incubate undigested residue in acid pepsin

—Dry residues and weigh

In Vitro Digestibility

Two-stage Van Soest IVDMTD

- —Incubate ruminal fluid with feed in buffer
- —Extract undigested residue in neutral detergent
- —Dry NDF residues and weigh

¥ In vitro methods measure different things

- —Single and two-stage T&T IV measure apparent DM digestibility
- —Two-stage Van Soest IV measures true DM digestibility

In Vitro Digestibility

Two-stage T&T IVDMD

- 48 hr fermentation highly correlated with in vivo DMD at 1xMaintenance
- DOES NOT mean that IVDMD = in vivo DMD
- Will be lower value than 2-stage VS IVDMTD because undigested residues contain microbial debris (part of in vivo endogenous loss

In Vitro Gas Production and Digestibility

¥ Usually a closed system

—Buffers do not work well and pH drops after 12-24 hr

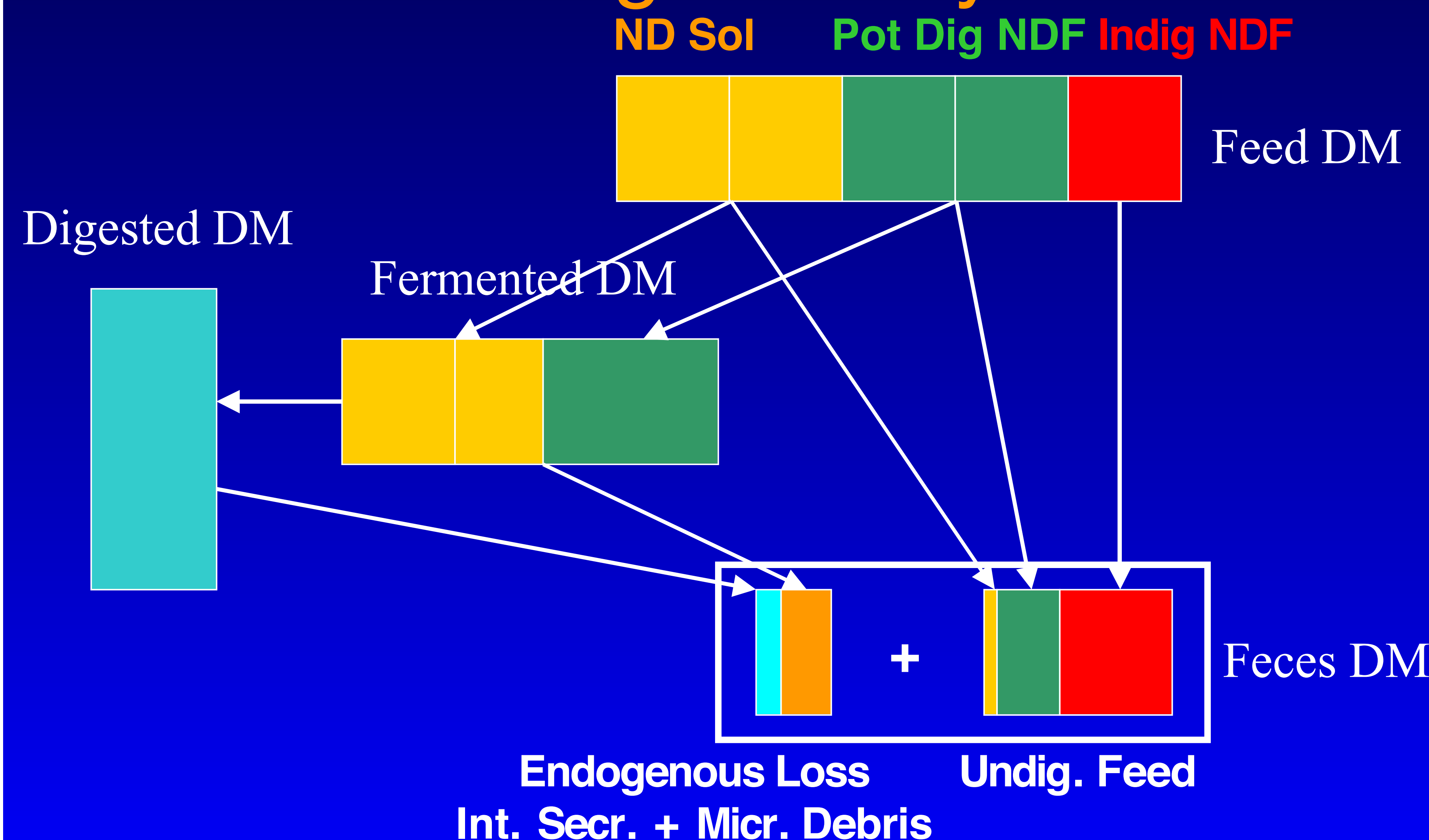
¥ Used to measure fermentation curves

—Assume that production of fermentation gas is proportional to DM disappearance

In Vitro Fermentation Time versus In Vivo Retention Time

¥ In vivo Retention Time DOES NOT equal in vitro fermentation time
  — i.e., digestion at 30 hr retention time DOES NOT digestion at 30 hr fermentation time
  — In vivo digestion = kd / (kd + kp)
  — In vitro digestion = 1 — DM*exp(-k*t)

Apparent versus True Digestibility



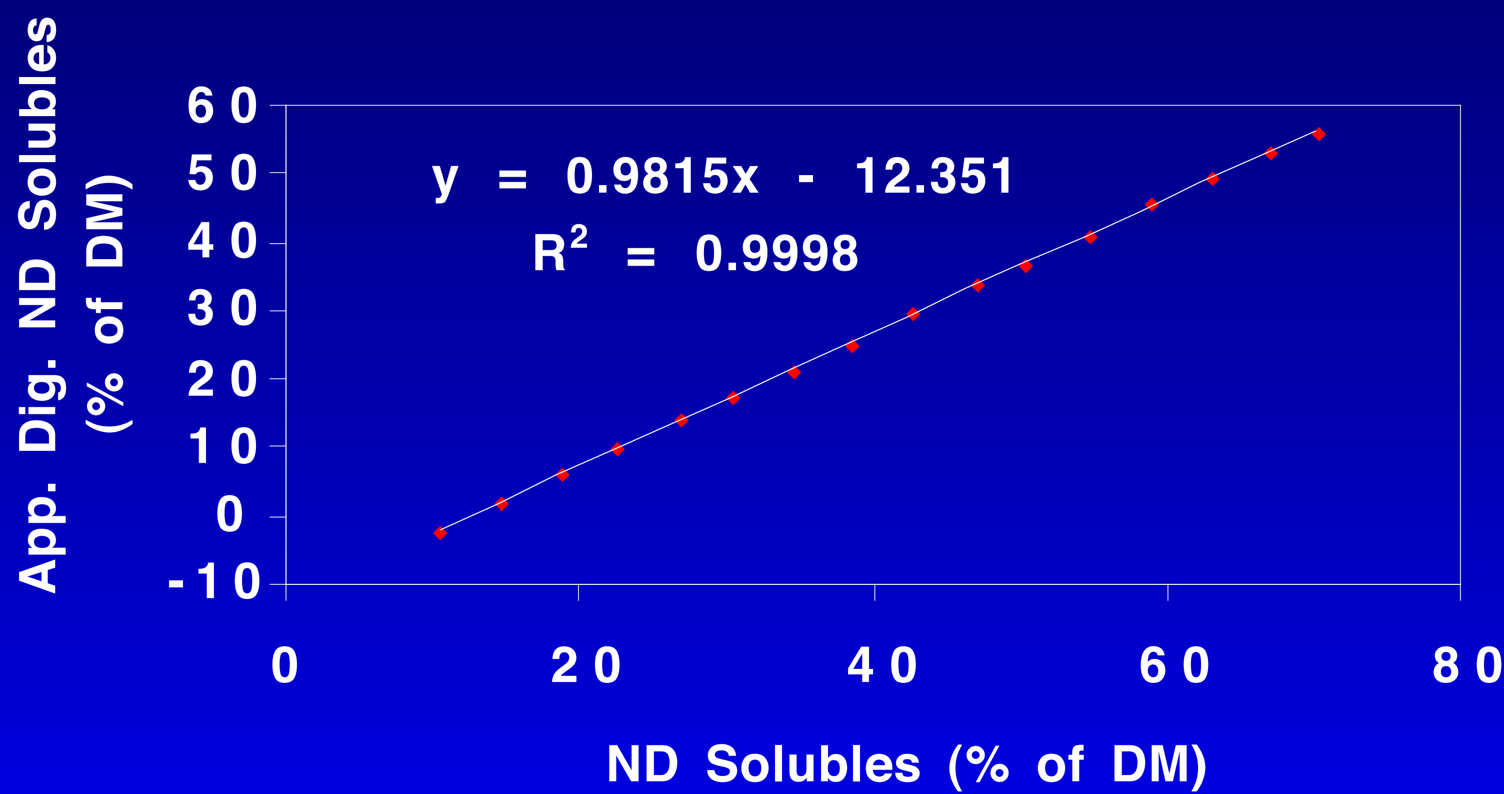
Apparent versus True Digestibility

- ¥ Apparent DM digestibility (% DMD) =
  - —100*[Feed DM —Fecal DM] / (Feed DM)
- ¥ DM true digestibility (% DMTD) =
  - —100*[Feed DM —Undig Feed DM] / (Feed DM)
- ¥ DMTD > DMD, e.g., 78% vs 65%

Apparent versus True Digestibility

- ¥ Measuring true digestibility is difficult because there are limited ways of estimating or measuring endogenous losses
  - —Regression for ideal nutritive entities
    - ¥ Have constant slope (estimates true dig.)
    - ¥ Have constant intercept (estimates End. Loss)
  - —Analytically remove endogenous losses from feces using neutral detergent

Using Regression to Estimate True Digestibility and Endogenous Loss



Ideal Nutritive Entities

¥ Have constant slope (true dig) near 0 or 1

¥ Have a negative intercept = endogenous loss

¥ Include

—dCP = -3.5 + 0.95*CP

—dEE = -1.5 + 0.98*EE

—dSolCHO ? = -2.0 + 1.00*SolCHO

—dNDS = -12.9 + 0.98*NDS

Summative Equations for Calculating Digestibility

¥ Based on the concept of Ideal Nutritive Entities

—Identify them

—Determine their true digestibilities and endogenous losses

—Sum them

¥ Largest Ideal Nutritive Entity is Neutral Detergent Solubles

¥ Other Ideal Nutritive Entities are CP, EE, Sugars, Soluble Carbohydrates, & Lignin

Summative Equations for Calculating Digestibility

- Largest Ideal Nutritive Entity is Neutral Detergent Solubles (NDS = 100 - NDF)
  - True Digestibility = 0.98
  - Endogenous Loss = -12.9
  - dNDS = -12.9 + 0.98*NDS
- Remaining fraction (NDF) is not ideal and its digestibility must be determined
  - dNDF = NDFD*NDF
- dDM = DMD = dNDS + dNDF

Summative Equations for Calculating Digestibility

- VS DMD = 0.98*NDS + NDFD*NDF — 12.9
- Dairy NRC (2001) and Milk2000 are an expansion of the VS summative equation
- NRC2001 calculated Total Digestible Nutrients (TDN) by subdividing NDS
  - TDN1x = tdCP + tdFA*2.25 + tdNFC + tdNDF — 7
  - FA = (EE — 1), NFC = 100 — (NDF — NDFICP) — CP — EE — Ash, CPTD = exp(-1.2*ADICP/CP), FATD = 1.0, NFCTD = 0.98*PAF and tdNDF = 0.75*(NDF — NDFICP — Lignin)*[1 — (Lignin/NDF)$^{2/3}$] or ??*IVNDFD*NDF

Summative Equations for Calculating Digestibility

¥ Milk2000 equation indicates that Starch is not an Ideal Nutritive Entity and removes it from NFC

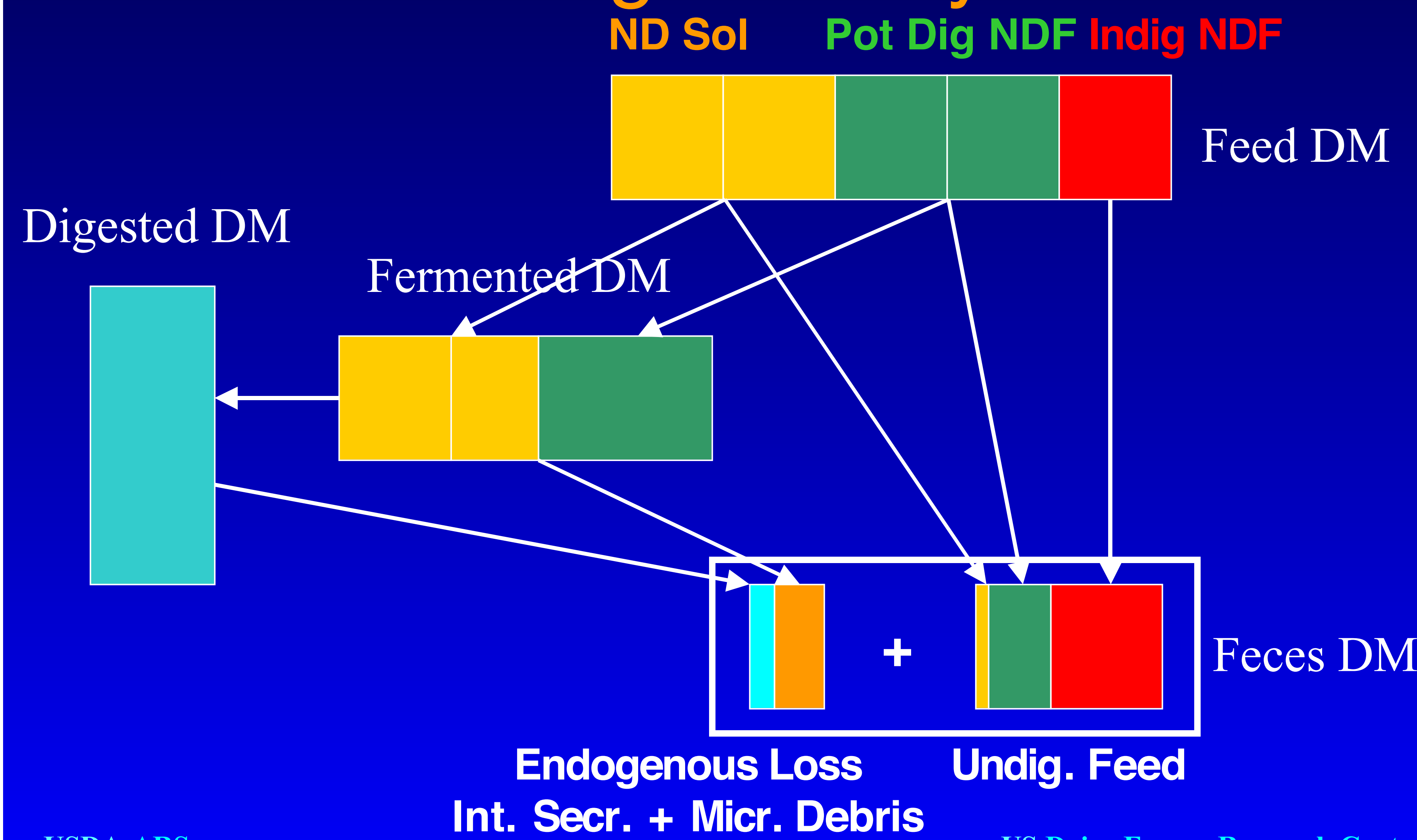
— TDN1x = tdCP + tdFA + tdNSNFC + tdST + tdNDF - 7

— Non-starch NFC (NSNFC) = (NFC — Starch) has a variable Starch Digestibility depending on corn silage %DM and processing

Summative vs Empirical Equations

- Emprical equations assume that the true digestibility of fiber is constant (or correlated with fiber content)
  - Works best for ADF vs NDF because ADF contains a higher proportion of lignin and indigestible residues
- Summative allows NDFD to vary
  - DMD = .98*NDS + NDFD*NDF — 12.9
  - = .98*(100-NDF) + NDFD*NDF — 12.9
  - = (98 — 12.9) - (98 — NDFD)*(NDF)

Apparent versus True Digestibility



Use Neutral Detergent to Remove Endogenous Losses from Feces

¥ ND will dissolve intestinal secretions

¥ ND will dissolve microbial debris

¥ But ND also dissolves undigested solubles

  — Only a problem in starchy feeds when starch is poorly digested, e.g, undamaged or coarsely cracked mature corn grain

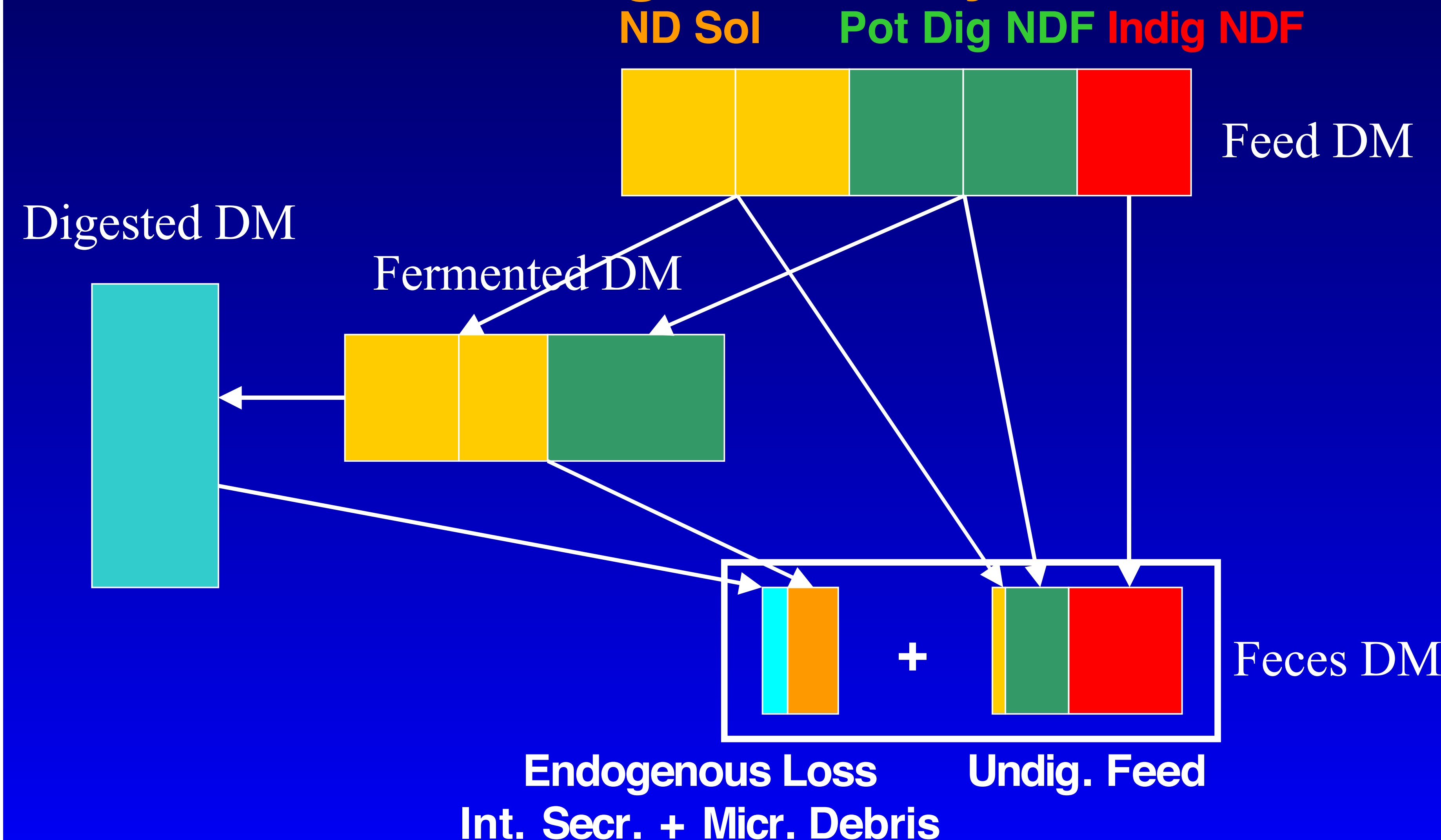
Use Neutral Detergent to Remove Endogenous Losses from Feces

¥ In most feeds undigested feed in feeds is primarily fiber (aNDF)

¥ Procedure is to extract feces with ND to remove endogenous losses and recover undigested feed

¥ % DMTD = 100*[Feed DM —(ND extracted fecal DM)] / Feed DM

Apparent versus True Digestibility



Digestible Nutrient vs Nutrient Digestibility

¥ Nutrient Digestibility IS NOT the same as digestible Nutrient —UNITS ARE IMPORTANT

¥ Nutrient digestibility is always expressed as a percentage of the nutrient, i.e., it is the fraction of the nutrient that is digested, a digestion coefficient

¥ digestible Nutrient is always expressed as a percentage of the feed DM, i.e., it is the fraction of feed DM that is digested nutrient

Digestible Nutrient vs Nutrient Digestibility

¥ To distinguish between them I suggest the following terminology and abbreviations

  —dNut = digestible nutrient = % of digested nutrient in feed DM

  —NutD = nutrient Digestibility = % of nutrient that is digested

¥ DM is an exception, dDM = DMD because digestible DM is expressed per unit of itself

Digestible Nutrient vs Nutrient Digestibility

¥ Example:

- —Cow eats 50 lb of feed containing 20% CP and excretes 15 lb of feces containing 15% CP
- —%CPD = 100*(Feed CP — Fecal CP) / Feed CP
- —Feed CP = 50 * 20/100 = 10 lb CP
- —Fecal CP = 15 * 15/100 = 2.25 lb CP
- —%CPD = 100*(10 — 2.25) /10 = 77.5%

Digestible Nutrient vs Nutrient Digestibility

¥ Example:

—digestible CP is always expressed in % of DM

—dCP = 100*(Feed CP —Fecal CP) / Feed DM

—dCP = 100*(10 — 2.25) lbs CP / 50 lb Feed DM

—dCP = 15.5% of DM

—dCP = CP * CPD/100 = 20 * 77.5/100 = 15.5% of DM

dNDF versus NDFD

¥ dNDF is better than NDFD (Mertens opinion)
- —dNDF=(100-iNDF) are actually measured in vitro
- —dNDF is actually used to calculate DMD

¥ dNDF = NDF*(NDFD/100)
- —NDFD separates the affect from NDF

¥ iNDF (and dNDF) related to Lignin as % of DM

¥ NDFD related to Lignin as % of NDF

dNDF &NDFD Equations

- ¥ Procedure:
  - ¥ Determine NDF of the original samples (**NDF, %DM**);
  - ¥ Run ~0.5 g (DMwt, **g**) IV for 48h, followed by a NDF (**NDFres, g**);
- ¥ IVDMTD = 100*[DMwt — NDFres) / DMwt)]; (%DM)
- ¥ iNDF = 100 - IVDMTD; (%DM)
- ¥ dNDF = NDF - iNDF; (%DM)
- ¥ NDFD = 100*dNDF/NDF; (%NDF)
- ¥ = 100*[NDF - (100 — IVDMTD)] / NDF

dNDF &NDFD Equations

- ¥ Example:
  - ¥ **NDF = 50 %DM**
  - ¥ **Sample DMwt = 0.5 g**
  - ¥ **NDFres = 0.1 g**
- ¥ IVDMTD = 100*[(0.5 - 0.1)/0.5]; = 80% DM
- ¥ iNDF = 100 - 80 = 20% DM
- ¥ dNDF = 50 - 20 = 30% DM
- ¥ NDFD = 100*(30 / 50) = 60% NDF

Calculating IVDMTD and IVNDFD

	Rep1	Rep2	Rep3	Rep4	Avg	SD
Sample wt	0.51	0.505	0.495	0.5		
Sample %DM	0.92	0.92	0.92	0.92		
Sample DM wt (A)	0.4692	0.4646	0.4554	0.4600		
Sample %NDF	44.21	44.21	44.21	44.21		
Sample NDF wt (B)	0.2074	0.2054	0.2013	0.2034		
NDF Res wt (C)	0.0802	0.0877	0.0836	0.0912		
dDM wt (A - C)	0.3890	0.3769	0.3718	0.3688		
Sample DM wt (A)	0.4692	0.4646	0.4554	0.4600		
IVDMTD	82.91	81.12	81.64	80.18	81.46	1.14
dNDF wt (B - C)	0.1272	0.1177	0.1177	0.1122		
Sample NDF wt (B)	0.2074	0.2054	0.2013	0.2034		
IVNDFD	61.34	57.29	58.47	55.17	58.07	2.58

dNDF equation for Corn silage

NDFD = 100*[NDF - (100 - IVDMTD)] / NDF

45.25										0.92	2.04
	IVDMTD					NDFD					
% NDF	Run1	Run2	Run3	Run4		Run1	Run2	Run3	Run4	SD IVDMD	SD NDFD
45.76	81.02	82.15	80.60	81.32		58.52	61.00	57.61	59.18	0.66	1.43
46.29	80.67	80.41	80.14	80.24		58.24	57.69	57.10	57.32	0.23	0.50
43.94	82.10	82.65	78.99	80.38		59.26	60.51	52.19	55.35	1.67	3.79
51.51	76.53	78.78	80.57	80.88		54.43	58.80	62.27	62.87	2.00	3.88
40.42	81.98	82.39	82.94	82.37		55.41	56.43	57.80	56.38	0.39	0.98
35.30	85.52	86.01	87.51	86.38		58.99	60.35	64.62	61.41	0.85	2.40
43.46	81.00	79.73	82.07	80.70		56.28	53.37	58.75	55.60	0.96	2.21
34.15	85.59	86.74	83.59	85.92		57.81	61.16	51.94	58.76	1.34	3.91
38.55	84.40	83.54	82.49	82.20		59.54	57.30	54.58	53.83	1.01	2.62
34.43	84.36	86.13	84.24	84.01		54.57	59.71	54.22	53.55	0.97	2.83
47.89	80.42	80.45	81.08	80.78		59.12	59.19	60.50	59.87	0.31	0.65
48.92	79.86	77.52	76.12	76.44		58.83	54.06	51.18	51.84	1.69	3.46
39.27	83.60	84.21	83.00	83.89		58.23	59.80	56.71	58.98	0.51	1.31

Conclusions

¥ Digestion is important

¥ Digestibility measurements are a function of method

¥ Know which IV method is used

  —Important for IVDMTD vs IVDMD

  —Only one way to measure NDFD

¥ dNDF is more important than NDFD (Mertens opinion)

¥ NDFD may have high SD and we may not be able to discriminate other than High, Medium and Low