

Analytical Approaches to the Nutritional Value of Corn

Donald A. Sapienza, Ph.D.
Manager, Nutritional Evaluation
Pioneer, A DuPont Company
Johnston, IA

Don.Sapienza@pioneer.com

515-685-3770

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2003 Minnesota Nutrition Conference



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Analytical Objectives

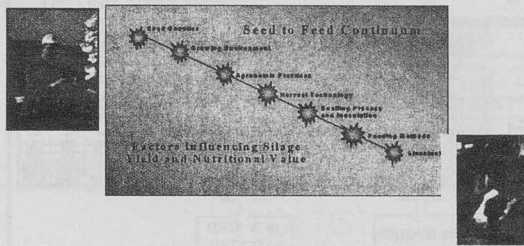
- ◆ What are the nutritional characteristics of Hybrid A that impact animal performance?
- ◆ How does Hybrid A differ nutritionally from Hybrid B?
- ◆ How does Hybrid A fit into a production ration?
- ◆ What are the economic benefits of Hybrid A?

Germplasm differences from an economic perspective!

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Seed to Feed Continuum Adding value to customer offerings



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Speaking seeds with a cow accent!

Animal Relevance

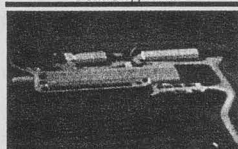
- ◆ Current focus is on ENERGY
- ◆ Supplying analytical values for energy equations
 - NUTRIENT CONTENT
 - > Dry matter, starch and NDF
 - > Protein and fat are future traits of interest
 - NUTRIENT AVAILABILITY
 - > Ruminant or monogastric
 - > Site...rumen, post-rumen (ruminant) or gastric, ileal (monogastric)
 - > Extent...how much is digested in a specific time
 - Digested.....that quantity that is digested
 - Un-digested.....that quantity that remains undigested
 - Un-digestible...that quantity that will "never" be digested
 - > Rate...how fast the nutrient is digested

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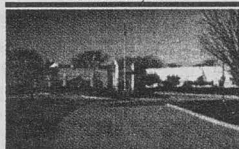
Where the analyses are done

Pioneer Livestock Nutrition Center
Polk City, Iowa



Chemical and physical analyses of fermented and non-fermented forages and grains and animal feeding trials.

PCC Forage and Grain Lab
Urbandale, Iowa

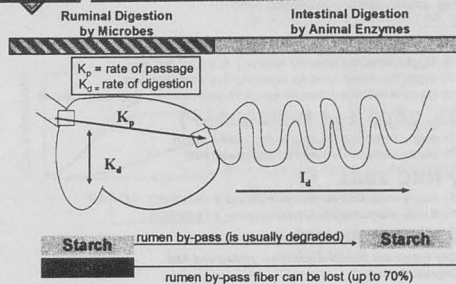


Chemical and physical analyses of grains, feed, meat, milk, eggs, tissues and digesta.

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Ruminant Digestion



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SEEDS OF ANIMAL NUTRITION

Monogastric Digestion

Digestion is mainly through the action of Animal Enzymes

Gastric acid and enzymes **Pancreatic and Ileal enzymes**

Gastric.....and Ileal

Starch

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SEEDS OF ANIMAL NUTRITION

ANALYTICAL FOCUS

Ingredient A B1 B2 C A B1 B2 B2 C

Ration 0 0 0 0 0 0 0 0 0 0

Relative Value
100.000 0.000

ANALYTICAL FOCUS

Chok = Sugar + VFA
ChokB = Avail Fiber
NDF = Chk2B + ChkC
Prob2B = Medium Degradation
ProbC = Unavail

ChokB1 = Starch + Pactive + B-Glucans
ChokC = Unavail Fiber
soP = ProbA + ProbB1
ProbB1 = Slow Degradation

-----Prob2-----

-----Total Carbohydrate (%)-----

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SEEDS OF ANIMAL NUTRITION

How and What is Measured

- ◆ Three Measurements
 - site, extent and rate of nutrient digestion
- ◆ Three Analytical Procedures
 - IV gas production, IV digestion and IS digestion
- ◆ Three Nutrients
 - DM, starch and NDF or
 - rumen degradable NDF, rumen degradable starch and post-ruminally degraded starch

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SEEDS OF ANIMAL NUTRITION

Inputs into MILK2000

University of Wisconsin-Corn Usage Evaluation System - Milk 2000 ver 7.4

Extension

| Line No | Item No | Unit | Value | Unit | Value | Unit | Value | Unit | Value | Unit | Value | Unit | Value | Unit | Value | Unit | Value | Unit | Value |
|---------|---------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|
| 1 | 100 | kg | 100 | kg | 100 | kg | 100 | kg | 100 | kg | 100 | kg | 100 | kg | 100 | kg | 100 | kg | 100 |

48h IS NDFD (substitute)

xh IV STRD
xh IS STRD (substitutes)

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SEEDS OF ANIMAL NUTRITION

How measurements can be used in ration models

- ◆ CPM
 - > To supply measured rates for ruminally degraded fast pool
 - > To supply measured rates for ruminally degraded slow pool
 - > To supply measured values for extent of post-ruminally degraded material
- ◆ Milk95, 2000 and Milk2000(+)
- ◆ Dairy NRC 2001
- ◆ Monogastric Models
 - > Dry Matter and Starch digestibility...gastric and ileal
 - > Digestible energy

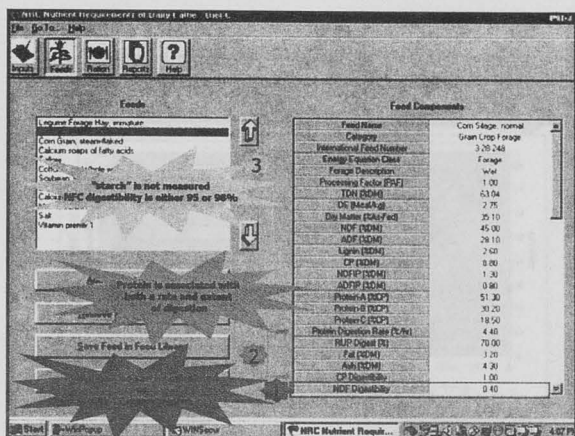
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SEEDS OF ANIMAL NUTRITION

Inputs into NEL in Dairy NRC, 2001

- ◆ NEL is no longer a static value
- ◆ NEL has become a **dynamic** property
- ◆ NEL is now a function of intake and production
- ◆ NEL of a feed is based on the animal situation
- ◆ NEL of a feed is calculated by using the OSU Summative Equation (TDN) plus a regression
- ◆ The OSU Summative Equation calculates TDN:
 - truly digestible NFC (non-fiber carbohydrates)..... equation 2-4a
 - truly digestible CP (crude protein)..... equation 2-4b
 - truly digestible FA (fatty acids)..... equation 2-4d
 - truly digestible NDF (neutral detergent fiber...cell walls)..... equation 2-4e minus a constant (7)

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The Analytical Method

Pioneer TPM
(Pioneer TriPartite Method)
(patent pending)

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Using outputs in the OSU equations

The OSU Summative Equation calculates TDN: Analysis measures:

- truly digestible NFC
- truly digestible CP
- truly digestible FA
- truly digestible NDF
- minus a constant (7)

Analysis measures:

| | | |
|--------|-------------|---------|
| Starch | Environment | *Rate |
| Sugars | | *Site |
| CC | Environment | *Extent |
| Fiber | | *Rate |
| | | *Site |
| | | *Extent |

1. Note: Analysis calculates "remainderCC" as the starch-free, sugar-free, cell contents recognizing the contributions of oil, soluble N and other non-fiber CHOs.

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Analytical Method of Choice

In-vitro (rumen, closed) gas production
(results used in CPM)

automated collection of gas production data

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Mathematics of outputs in the OSU equations

OSU Equations calculate TDN: Pioneer calculates TDN:

- truly digestible NFC (2-4a)
- truly digestible NDF (2-4e)

OSU Equations:

$$0.98 (100 - ((\text{NDF} - \text{NDF}(\text{CP}) + \text{CP} + \text{EE} + \text{Ash})) * \text{PAF})$$

$$0.75 ((\text{NDF} - \text{NDF}(\text{CP}) - \text{L}) * (1 - (\text{L} / (\text{NDF} - \text{NDF}(\text{CP})^{0.667})))$$

Pioneer measures:

(Starch, Sugars and CC) * $\left(\frac{((\text{Str} + \text{SS} + \text{CC}) * (\text{Kds} / (\text{Kds} + \text{Kps})))}{(\text{Str} * \text{deg})} \right)$

(NDF) * $\left(\frac{(\text{NDF}) * (\text{Kdf} / (\text{Kdf} + \text{Kpf}))}{(\text{Kdf} / (\text{Kdf} + \text{Kpf}))} \right)$

NOTE: Both Kps and Kpf are estimated.

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Gas Production Data

Example Output

Results: Schofield and Peil, 1995
(curve-fitting algorithms)

- curve peeling for pools
 - Total DM: _____
 - Fast Pool: _____
 - Slow Pool: _____
- logarithmic rates

Other results:

- lag time (X-intercept)

Advantages:

- msmts every 20 minutes
- temperature control
- agitation

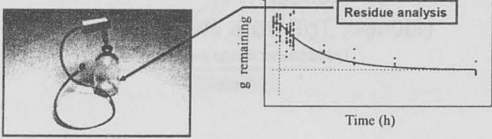
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SEEDS OF ANIMAL NUTRITION

Analytical Methods of Choice

In-vitro (rumen, closed) residue (<24h)
In-situ residue (>24h)

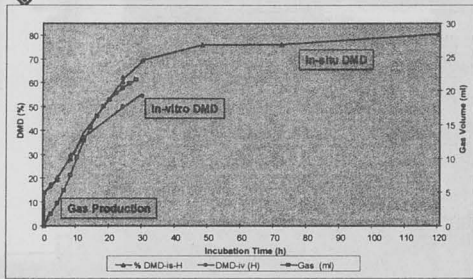
- ◆ **Milk95, 2000 and beyond**
 - To supply measured values into degradable starch
 - To supply measured values into degradable NDF
- ◆ **Dairy NRC 2001**
 - To supply measured values into equation 2-4a (tdNFC)...95 or 98 or some other value
 - To supply measured values into equation 2-4e (tdNDF)...tdNDF



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Closed in-vitro (gas or residue) has a maximum incubation time



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SEEDS OF ANIMAL NUTRITION

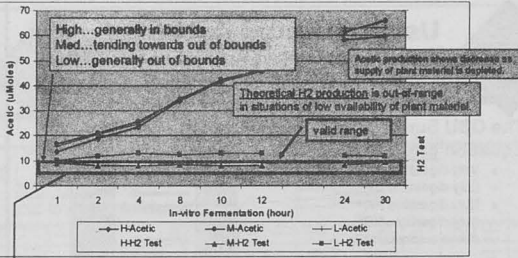
Reasons for combining IV and IS residue analysis

- ◆ IV only valid ≤ 30 hours
- ◆ Asymptotic curve
 - Add in-situ ruminal residue production
- ◆ However, IS unstable and hard to standardize
 - Stabilizing in situ
 - In situ appeared to be most variable ≤ 24 hours
 - Particle loss from the bag was largest contributor
 - Standardizing in situ

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SEEDS OF ANIMAL NUTRITION

Reasons for combining IV and IS residue analysis



The basis for this calculation is:

- known carbon supplied from plant material consumed during the ruminal fermentation... residue analysis
- known volume of gas produced and the quantity of individual VFAs (C2, C3 and C4)
- calculate CH₄ produced
- calculate H₂ produced
- compare H₂ ratio acceptable range: 0.88 to 1.0

Demeeyer and van Nevel, 1975, 1991
Immig, 1996, 1999 and 2001

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SEEDS OF ANIMAL NUTRITION

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SEEDS OF ANIMAL NUTRITION

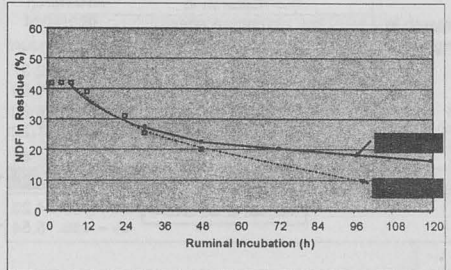
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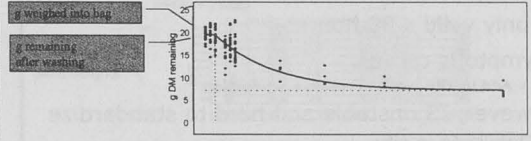
Curve Fitting... asymptote and curve "extension"



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Accounting for "lost" particles

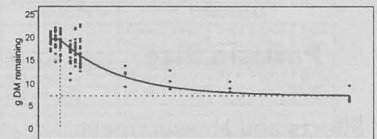


- > Particle loss can be measured independently of in-situ incubation by washing bags in cold water.
- > Analysis DOES NOT EQUATE particle loss with A-fraction because not all plant material "lost" from the bag is degraded as rapidly as A-fraction specifications.

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Curve Fitting



Residue Production (for each constituent, DM, starch, and NDF):

$$y = E + (I - E) \exp(-(t - L)R) \text{ for } t \geq L$$

- Where:
- y = residue remaining at particular time (t)
 - E = maximum amount digested
 - I = A-fraction (instantaneously available)
 - L = lag period (calculated from gas data)
 - R = rate of degradation

Outliers are >2.5 SD at each time point.

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The screenshot shows a software window titled "Calculating DM, NDF, and A-fraction". It contains a table with columns for "Ingredient" and "Ration" (A, B1, B2, C) and rows for "DM", "NDF", "ProtE", and "ProtC". Below the table, there are text boxes defining:

- ChoA = A-fraction = Sugar + VFA
- Direct measurement of A-fraction
- Measurement of rate or extent of A-fraction

 A box labeled "TPM approach" with an arrow points to the "ChoA" definition.



Reasons for combining IV and IS residue analysis

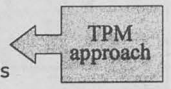
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Measuring A-fraction

- ◆ **Direct Measurement** (Mathis, 2001 Animal Feed Science and Technology, 93:31)
 - cold-water wash of the original plant material
 - > weight lost upon washing
 - > effect of particle size
 - > effect of procedural details
 - summation of the measured concentrations of sugar and VFAs
- ◆ **Indirect Measurement**
 - data is available to calculate the Y-intercept of the gas production curves



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Reasons for combining IV and IS residue analysis

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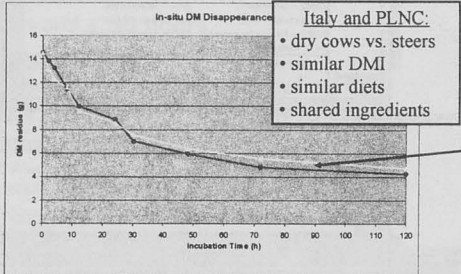
Standardized in situ has variation comparable to literature values

| | % starch in starting material | % starch in residue after 24 hours | | % starch degraded after 24 hours | |
|--------|-------------------------------|------------------------------------|------|----------------------------------|----------------|
| Rep# 1 | 26.42 | An# 1 | 6.66 | 8.57 | 77.55 |
| Rep# 2 | 22.35 | An# 2 | 7.55 | 6.71 | 79.65 |
| Rep# 3 | 22.03 | An# 3 | 8.52 | 6.48 | 71.33 |
| Rep# 4 | 22.92 | An# 4 | 5.28 | 5.22 | 76.97 |
| Mean | 23.43 | | 6.87 | | 76.41 |
| SD | 2.03 | | 1.28 | | CV = 5.30 4.06 |
| Mean | | | | | 84.23 |
| SD | | | | | CV = 6.58 5.54 |

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Standardization



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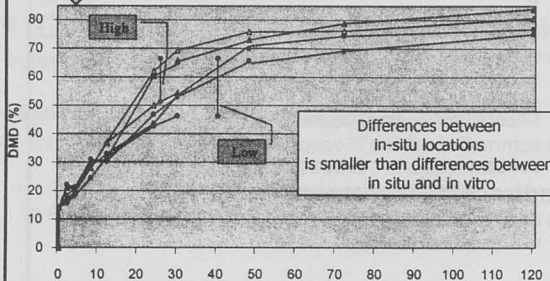
Particle Size

Effects and Measurement

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Standardized in situ versus in vitro



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| Feed Name | Conc Stage normal |
|---------------|-------------------|
| Crude Protein | 320-248 |
| Cellulose | 100 |
| Starch | 63.04 |
| CP (DM) | 2.7% |
| CP (DM) | 20.1% |
| CP (DM) | 45.0% |
| CP (DM) | 28.1% |
| CP (DM) | 3.5% |
| CP (DM) | 8.8% |
| CP (DM) | 1.9% |
| CP (DM) | 0.8% |
| CP (DM) | 57.2% |
| CP (DM) | 30.7% |
| CP (DM) | 18.5% |
| CP (DM) | 4.4% |
| CP (DM) | 70.0% |
| CP (DM) | 3.3% |
| CP (DM) | 4.3% |
| CP (DM) | 1.0% |
| CP (DM) | 0.4% |



Sample preparation must not distort agreement between lab (DDM) measurements and animal responses

| DDM | Treatments | | | | |
|--|------------|------------|-----------|-----------|-----------|
| | Fresh >8mm | Dried >8mm | Dried 4mm | Dried 3mm | Dried 2mm |
| 24-hour ruminal in-situ DM disappearance | | | | | |
| mid-maturity | 52.4a | 56.3c | 59.8 | 61.9 | 62.5 |
| late-maturity | 39.9b | 49.1d | 60.1 | 65.1 | 61.3 |
| 48-hour traits in-situ DM disappearance | | | | | |
| mid-maturity | 68.0a | 67.0c | 72.4 | 74.0 | 75.9 |
| late-maturity | 57.7b | 61.2d | 74.2 | 78.5 | 77.3 |

In-vivo Milk (DMD) (lbs/c/d)
71a 82a
52b 79b

Johnson et. al., 2002

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Measuring effect of particle size (PS)



Sample of sample weight (g) (TPAS2 2002)

| course | mm | area weight | total weight | sample weight | distribution | inclusion error |
|-------------|---------|-------------|--------------|---------------|--------------|-----------------|
| course 15 | 85.100 | 155.41 | 0 | 0 | 0 | 0.00 |
| course 15 | 50.000 | 157.7 | 0 | 0 | 0 | 0.00 |
| course 8.5 | 548.700 | 587.70 | 3 | 1 | 0.000000 | 3.00 |
| course 8.5 | 218.000 | 535.00 | 10 | 10 | 0.000000 | 10.00 |
| course 4.75 | 303.000 | 362.00 | 30 | 30 | 0.000000 | 30.00 |
| course 3.00 | 423.000 | 423.00 | 10 | 10 | 0.000000 | 10.00 |
| course 2.50 | 360.000 | 213.40 | 10 | 10 | 0.000000 | 10.00 |
| course 1.18 | 248.700 | 36.00 | 10 | 10 | 0.000000 | 10.00 |
| total | 0.0 | 301.700 | 307.00 | 0 | 0 | 0.00 |
| total | 0.0 | 288.000 | 300.00 | 0 | 0 | 0.00 |
| total | 0.0 | 288.000 | 300.00 | 0 | 0 | 0.00 |

(Mertens, CNC 2002)

STRD (% of starch) 56.87

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Sample preparation must not distort agreement between lab (starch) measurements and animal responses

| STARCH | Treatments | | | | |
|--|------------|------------|-----------|-----------|-----------|
| | Fresh >8mm | Dried >8mm | Dried 4mm | Dried 3mm | Dried 2mm |
| 24-hour ruminal in-situ Starch disappearance | | | | | |
| mid-maturity | 82.5a | 82.3c | 97.0 | 98.2 | 97.3 |
| late-maturity | 52.2b | 71.2d | 95.3 | 93.9 | 91.4 |
| 48-hour traits in-situ Starch disappearance | | | | | |
| mid-maturity | 89.0a | 94.5c | 99.1 | 99.8 | 100 |
| late-maturity | 66.4b | 79.5d | 99.2 | 100 | 100 |

Johnson et. al., 2002

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Accounting for PS effect

◆ Mertens' equation (Mertens, CNC 2002)

$$\text{Corn silage StarchD (\% of starch)} = 117 - 0.586(\text{CS_DM}\%) - 0.00144(\text{CS_DM}\%)(\% \text{Starch} > 4.75)$$

with a maximum of 98%.

◆ Analysis QA-check

- Measured ruminal and post-ruminal STRD
- Calculate TT STRD
- Compare TT STRD with Mertens' STRD

◆ "adjusted" value becomes STRD and can be combined into Equation 2-4a

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Sample preparation must not distort agreement between lab (NDF) measurements and animal responses

| NDF | Treatments | | | | |
|---|------------|------------|-----------|-----------|-----------|
| | Fresh >8mm | Dried >8mm | Dried 4mm | Dried 3mm | Dried 2mm |
| 24-hour ruminal in-situ NDF disappearance | | | | | |
| mid-maturity | 28.7a | 31.8c | 22.5 | 27.8 | 28.6 |
| late-maturity | 19.2b | 23.1d | 29.7 | 33.8 | 28.4 |
| 48-hour traits in-situ NDF disappearance | | | | | |
| mid-maturity | 48.0 | 45.3 | 45.5 | 48.3 | 54.5 |
| late-maturity | 40.3 | 44.2 | 45.9 | 56.2 | 52.4 |

Johnson et. al., 2002

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Starch and Fiber

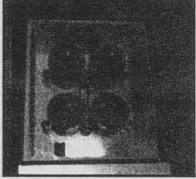
Associative effects
and
Inputs to CPM

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Monogastric Starch Digestion

In-vitro Incubation



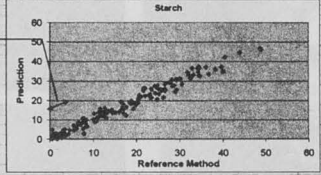
Standard semi-purified enzymes with pepsin pre-treatment

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SEEDS OF ANIMAL NUTRITION

TPM: NIRS Calibration Statistics Starch in Residue

Possible evidence that starch is highly digestible



| | BSE | RSD | SECY | 1-VR | calibration stats |
|-----|-------|---------|------------------|----------------|-------------------|
| STR | 1.885 | 0.973 | 2.143 | 0.688 | |
| CA | +3.0 | | <3.5 | similar to RSD | |
| | RSD | SEP (S) | validation stats | | |
| STR | 0.63 | 2.271 | | | |
| CA | | +3.0 | | | |

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TriPartite Method (patent pending)

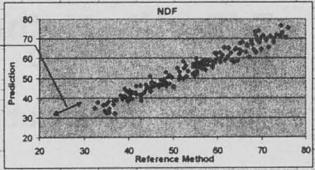
TPM: using NIRS

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SEEDS OF ANIMAL NUTRITION

TPM: NIRS Calibration Statistics NDF in Residue

Possible evidence of Un-digestible NDF




| | BSE | RSD | SECY | 1-VR | calibration stats |
|-----|-------|---------|------------------|----------------|-------------------|
| NDF | 2.618 | 0.948 | 3.181 | 0.624 | |
| CA | +3.0 | | <3.5 | similar to RSD | |
| | RSD | SEP (S) | validation stats | | |
| NDF | 0.78 | 3.167 | | | |
| CA | | +3.0 | | | |

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SEEDS OF ANIMAL NUTRITION

TPM: Using NIRS



•Nutrients Measured
 > routinely:
 ✓DM, starch and NDF
 ✓others: on demand

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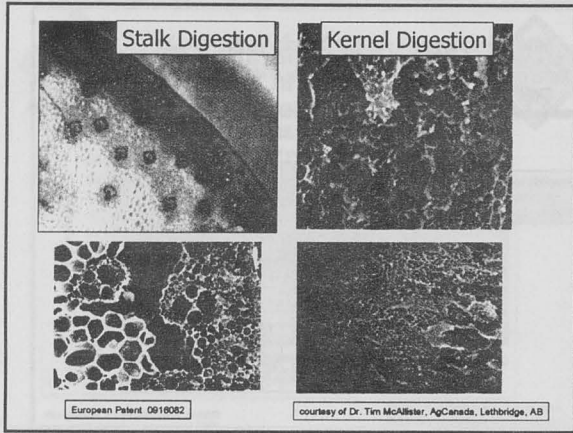

SEEDS OF ANIMAL NUTRITION

The Physical and Chemical aspects of Digestion (stalks and kernels)

NDF


Starch

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TPM: Extends traditional lab values and calculations

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TriPartite Method

(patent pending)

Summary of field utility

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Importance of Matching Feeds


Diet changes made during a cash-crunch need to be examined. Many additives and special ingredients are being re-evaluated as milk prices drop.

In many cases, there is a higher return on the feeding investment by formulating diets with more forage.

Increasing forage in the diet improves milk income over feed costs as long as the forage quality is good and concentrates are well matched to the forages. Under these conditions forage drives the rumen to produce more volatile fatty acids for energy and grow more rumen microbes that become high-quality 'animal' protein sources. However, if forage quality is not good, or forage quality is inconsistent - high forage diets may hurt production and reduce income over feed cost.


Kurt Ruppel, M.S., P.A.S.
Cargill Animal Nutrition
Dairy Management Specialist

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TPM: field utility

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Recent Testimonials

Testimonial #1:
We ran a TPM analysis for a nutritionist associated with a California dairy (milks 3000 cows).

The TPM suggested their corn silage was much more energy dense (NE-L = .81) than they had given it credit from other standard analyses (they had it balanced in at NE-L = .71). So the nutritionist increased corn silage while backing down the steamed rolled corn.

Cows responded by resuming normal fat test (it had been depressed).

Nutritionist and producer were very pleased and said they guessed the new test really does evaluate corn silage better than what they had been using.

Testimonial #2:
We ran TPM analyses for another experienced nutritionist.

Nutritionist commented that the results showed him objectively what adjustments he must make to traditional compositional analysis. In the past, he has made these adjustments 'subjectively' based on his experience. The analytical values provided confirmed his subjective adjustments.

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TPM: animal validation (Shaver, CNC, 2002)

A preliminary analysis for this paper of analytical data (MILK2000 and Pioneer TPM inputs to estimate corn silage NE_e content) and animal performance data (DMI, milk yield, and BW change) from nine corn silage treatment comparisons from four controlled experiments (Satter et al., 2000; Schwab et al., 2002) and two commercial dairies showed an average predicted minus observed corn silage treatment difference of -1.4 and -0.5 lb. milk/cow/day for MILK2000 and Pioneer TPM, respectively.

MILK2000 and Pioneer TPM agreed within 2 lb. milk/cow/day of each other for 7 of the 9 treatment comparisons. An average predicted minus observed corn silage treatment difference of -2.7 lb. milk/cow/day was observed using an ADF-based prediction of corn silage NE_e content (Schmid et al., 1976).

Attempts are underway to add more in-vivo data to these validations.

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