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Understanding Forage Yield, Nutritive Value and Quality

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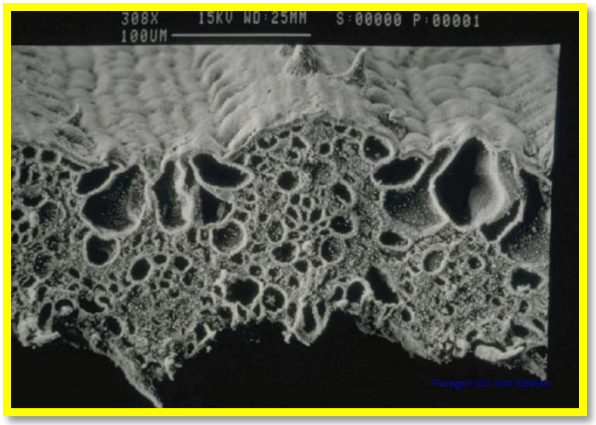
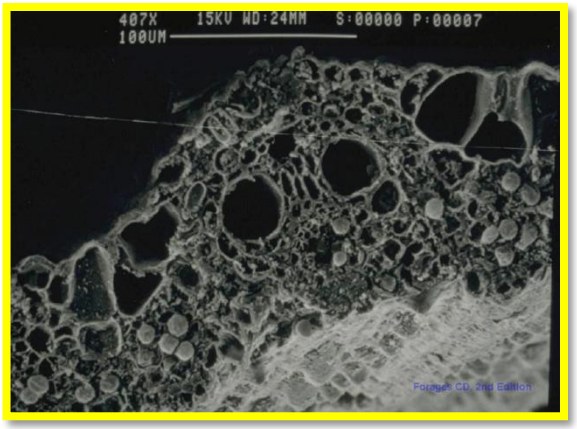
Ruminant Use of Forage Crops

- **Microbial breakdown of fiber in digestive tract**
  - **Cellulose**
  - **Hemicellulose**

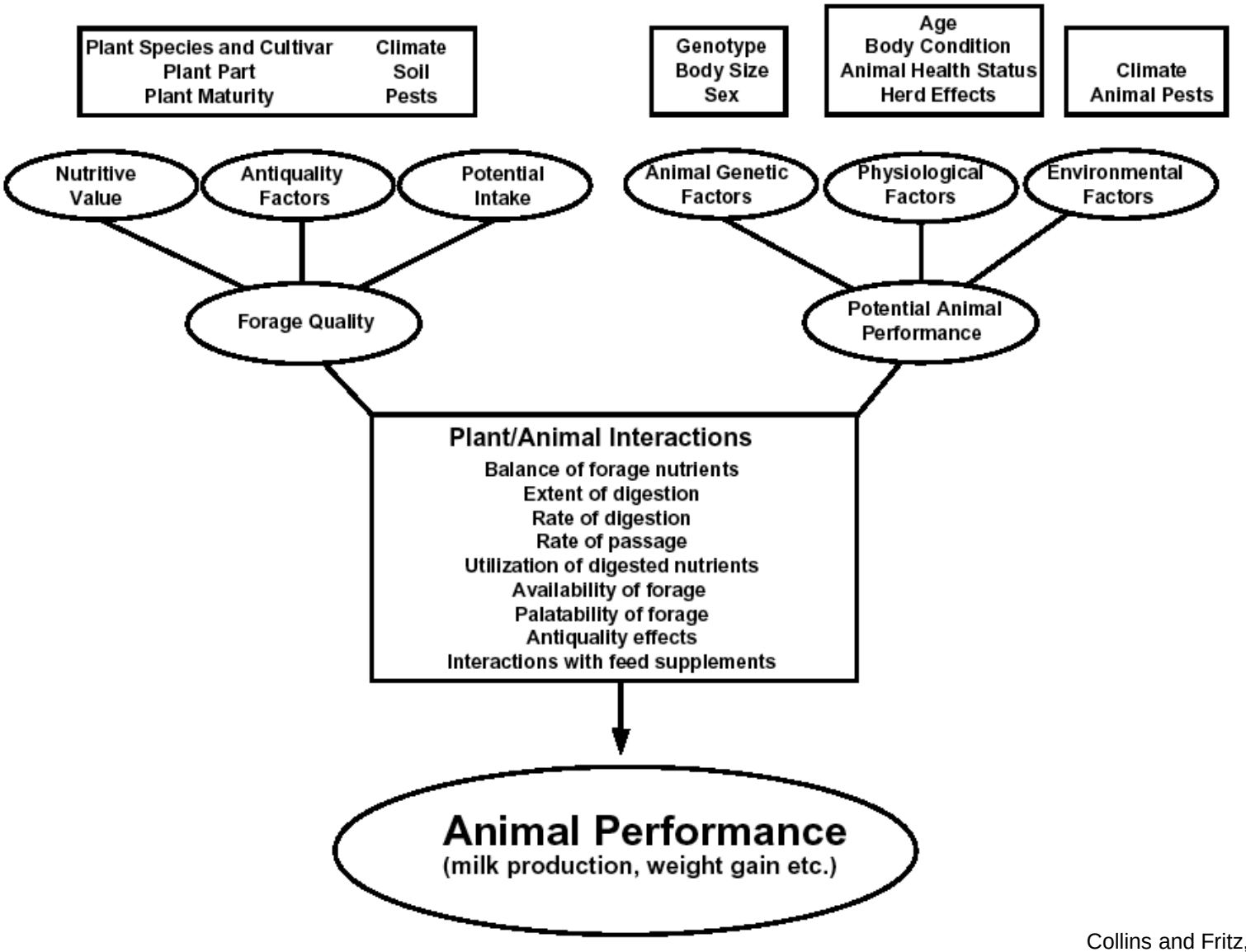




What is Forage Quality

- **Ultimate measure is animal performance**
- **Other factors include:**
  - **Nutritional value**
  - **Voluntary intake**
  - **Anti-quality constituents**

What is Forage Quality



Collins and Fritz, 2003

General Forage Composition

- Cell contents
  - Proteins
  - Organic acids
  - Lipids
  - Starch
  - Sugars
- 90-100% digestible

- Cell walls
  - Structural carbohydrates
    - Cellulose
    - Hemicellulose
  - Lignin
  - Cutin
  - Silica
  - Pectin
- Variable digestibility
- Major determinants of animal performance on forage diets

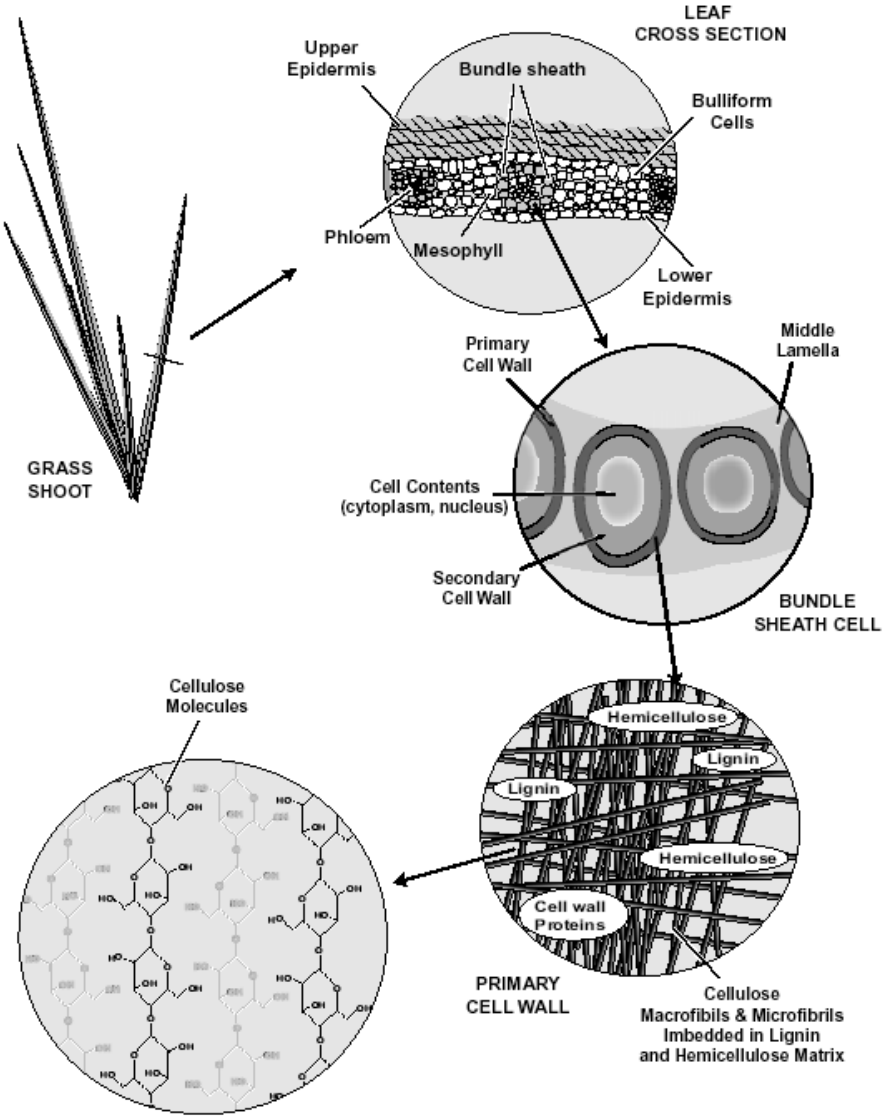
Cell Wall Carbohydrates

- **Cellulose**
  - **Glucose connected together**
  - **Interlinked to form microfibrils**
  - **Slowly digested**
- **Hemicellulose**
  - **Multiple carbohydrate types connected**
  - **3 to 4 times higher in grasses than legumes**
  - **Variably digested**
- **Pectins**
  - **Found in middle lamella and primary cell wall**
  - **Glue cells together**
  - **Higher in legumes than grasses**

Lignin

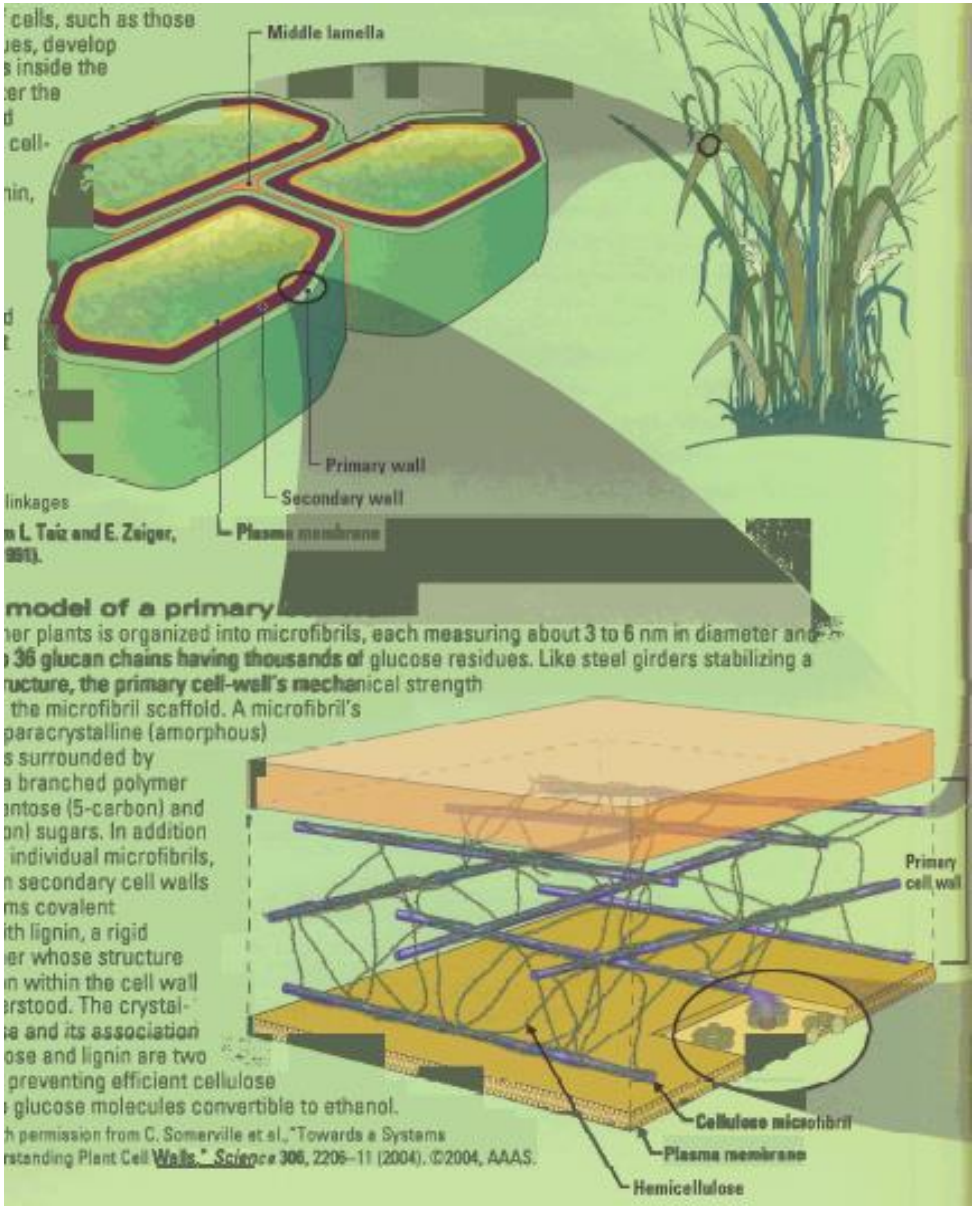
- **Phenolic compound**
- **Adds rigidity to plant**
- **Interspersed in cellulose**
- **Indigestible**
- **Suppresses digestibility of other cell wall material**
- **3-12% lignin in forage crops**
- **Higher in legumes than grasses**

The Cell Wall



Collins and Fritz, 2003

The Cell Wall



Forage Nitrogen

- **Protein N**
  - **60-80% of total N in fresh forages**
  - **Generally, legumes > cool-season grasses > warm-season grasses**
  - **Digestible protein N**
  - **Indigestible protein N**
- **Nonprotein N**
  - **20-40% of total N in fresh forages**
  - **Nitrates**
  - **Free amino acids**
  - **Small peptides**
- **Crude protein**
  - **Includes protein N and nonprotein N**
  - **Equals total N x 6.25**

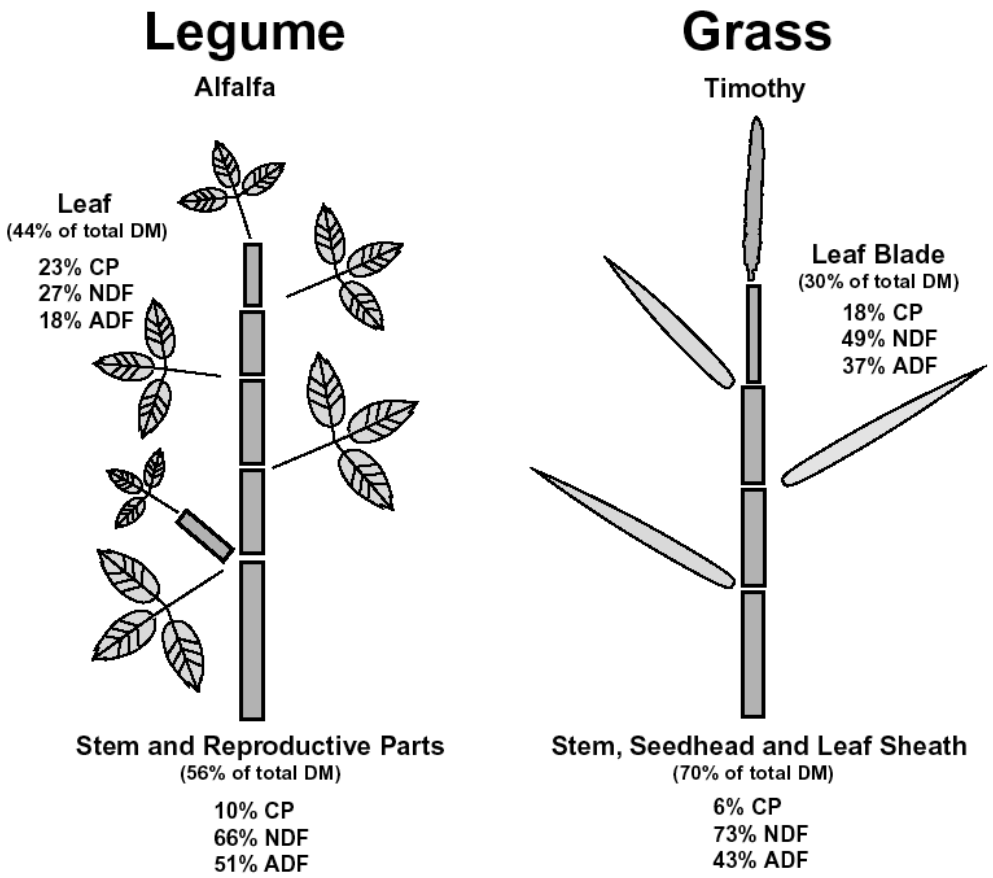
Factors Affecting Forage Quality

- Forage species
- Stage of maturity
- Harvest conditions
- Temperature
- Moisture
- Soil fertility
- Cultivar
- Others

Plant anatomy and morphology

Plant Anatomy and Morphology

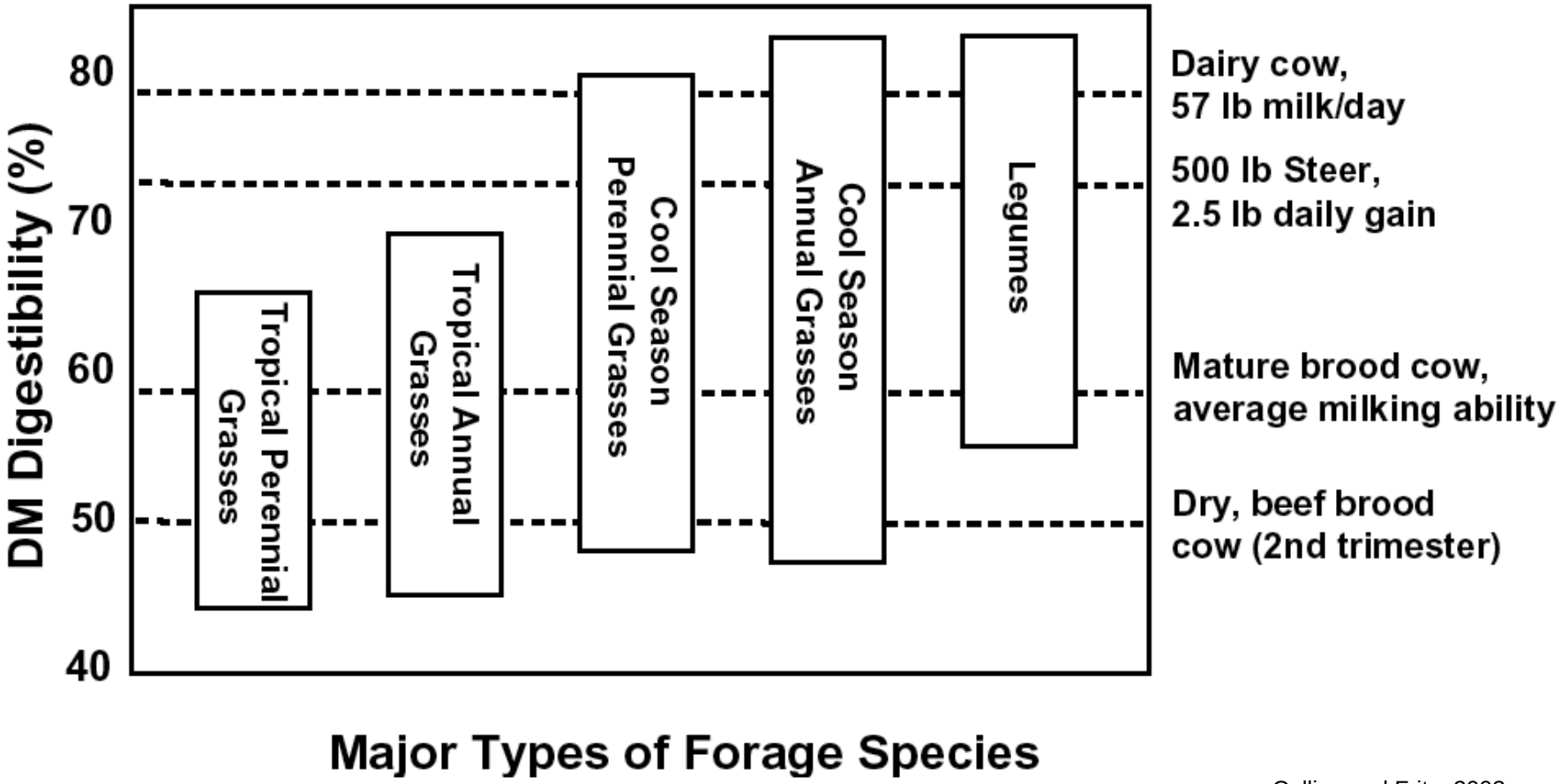
- **Affected by other management factors and species**
- **Leaves higher quality than stems**
- **Cell types impact quality**
- **Leaf to stem ratio**



Collins and Fritz, 2003

Plant Species

- **Generally, legume > cool-season grass > warm-season grass**



Collins and Fritz, 2003

Plant Species

Table 16.1. Tissue types in leaf cross sections of a warm-season (bermudagrass) and a cool-season (tall fescue) forage grass

Cell type	Bermudagrass	Tall fescue
	% of leaf cross section area	
Vascular bundles	37	11
Epidermis	26	19
Sclerenchyma	10	7
Mesophyll	27	62

Source: Akin and Burdick 1975.

Table 16.2. Forage quality of alfalfa and timothy components of a mixture

Species	Crude protein (%)	NDF (%)	ADF (%)	Cell wall digestibility[a]	Cell wall digestion rate[b] (%/hour)
Alfalfa	15.8	49	34	46	5.3
Timothy	9.5	66	38	57	2.3

Source: Collins 1988.

[a]The percentage of the sample NDF lost during 72 hours of incubation in a rumen fluid-buffer solution mixture.

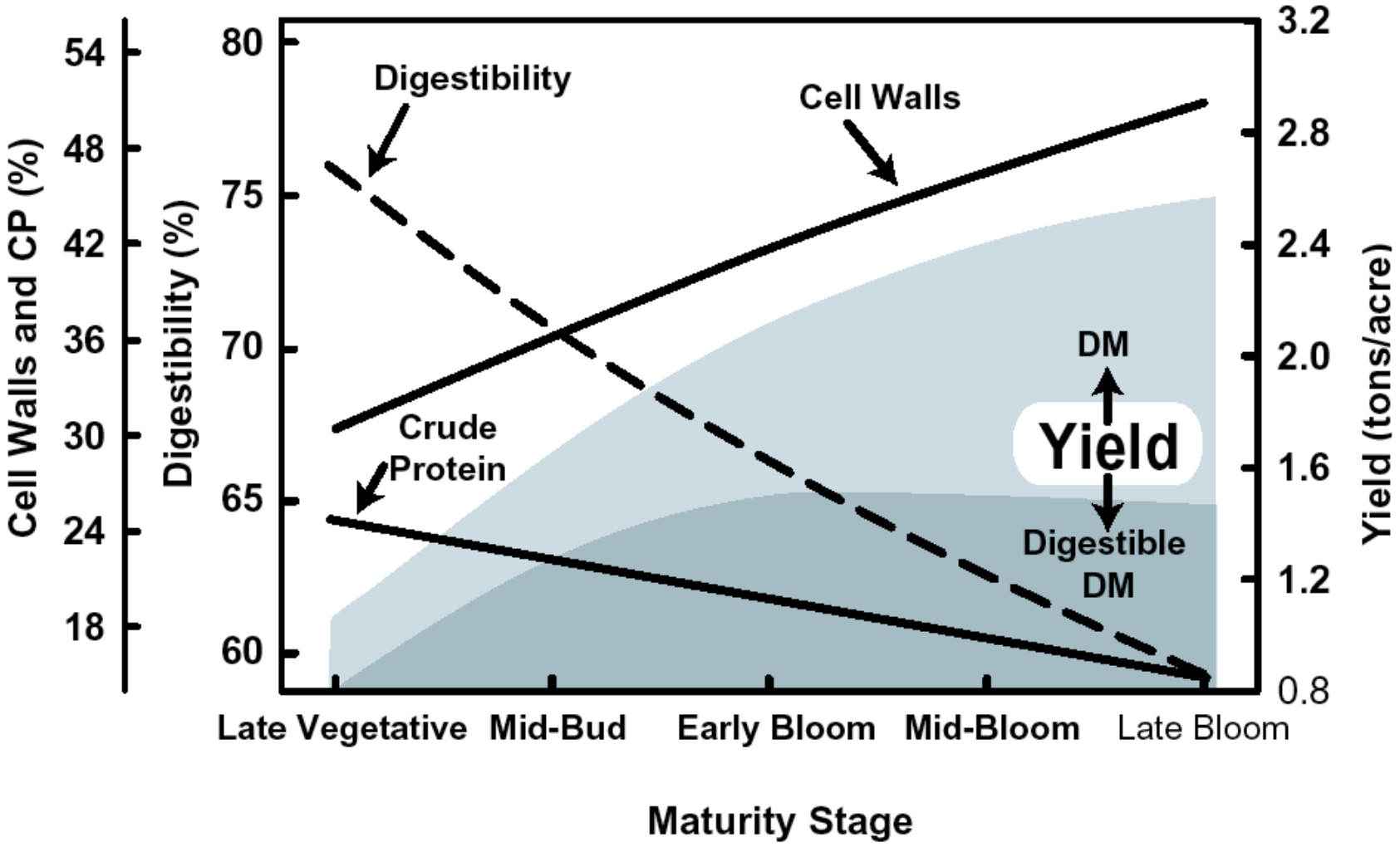
[b]The percentage of the digestible cell wall material disappearing during each hour of incubation.

Collins and Fritz, 2003

Stage of Maturity

- **Quality declines as forages mature**
- **Leaf:Stem ratio declines with maturity**

Stage of Maturity



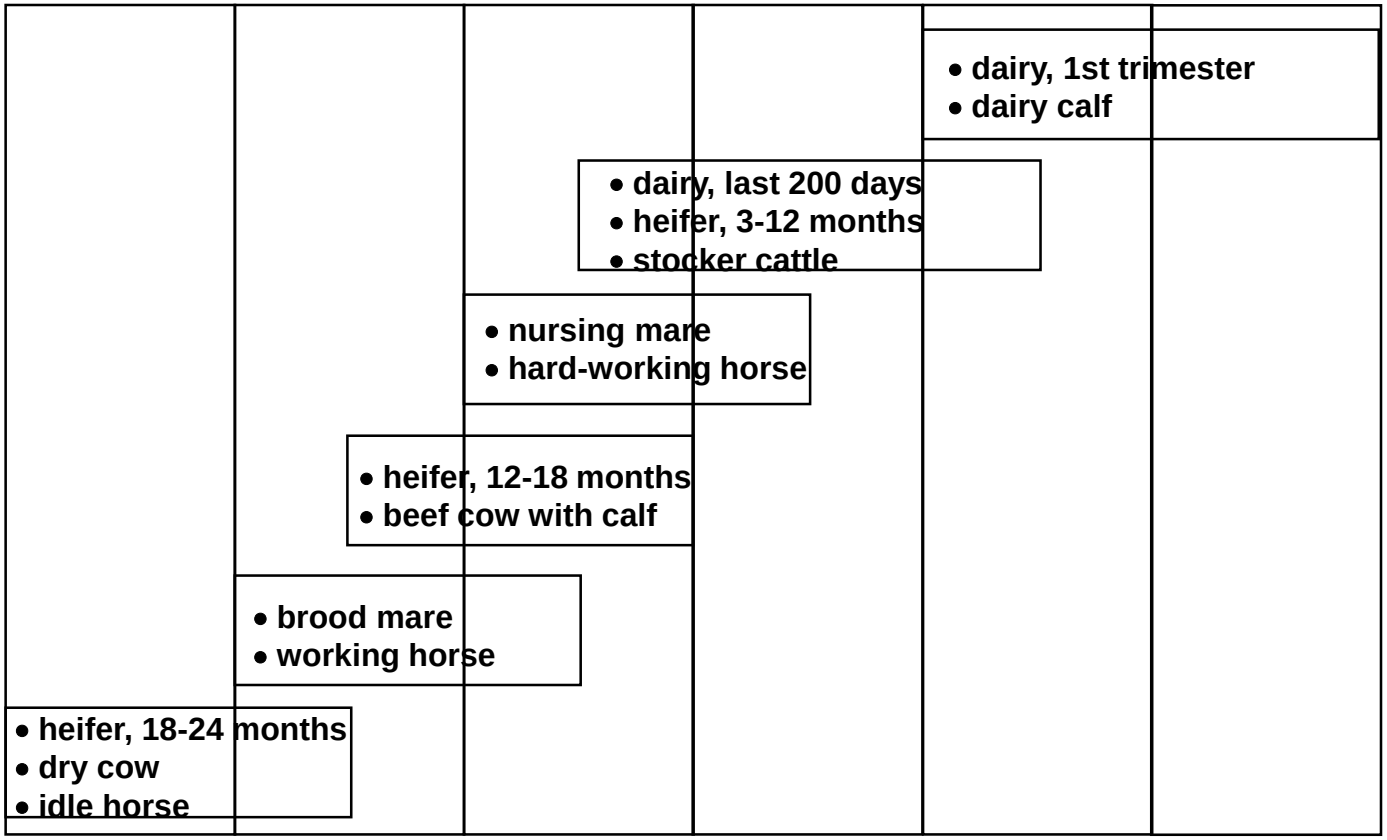
Collins and Fritz, 2003

Miscellaneous Forage Quality Factors

- Grass/legume mixtures
- Fertilization (grasses mainly)
  - Possibly increase quality
  - Increase yield
- Environment
  - Temperature
  - Cutting time during the day
- Cultivar

Evaluating Forages for Quality

Forage quality needs of cattle and horses



Adapted from Undersander et al., 1994

Interpreting Forage Test Results

CP

ADF

RFV

DMI

TDN

Minerals

NDF

Moisture

DM

DDM

Adj.-CP

ADIN

Energy

ADF-CP

Interpreting Forage Test Results

Definitions

Dry matter (DM): Amount of plant sample remaining after all water has been removed. USE THESE VALUES.

Crude protein (CP): Total nitrogen multiplied by 6.25. Includes both true protein and nonprotein nitrogen.

Neutral detergent fiber (NDF): Percentage of fiber or cell walls in a feed, inversely related to intake, and only partially digestible. Made up primarily of hemicellulose, cellulose, and lignin.

Acid detergent fiber (ADF): Percentage of highly indigestible and slowly digestible plant material. Composed primarily of cellulose and lignin.

Interpreting Forage Test Results

Definitions

Digestible dry matter (DDM): Percentage of sample which is digestible to an animal. Often calculated from ADF.

Dry matter intake (DMI): An estimate of the amount of forage an animal will consume if fed entirely the tested forage. Commonly calculated from NDF.

Relative feed value (RFV): An index used to compare like forages. RFV is calculated from DDM and DMI. Full-bloom alfalfa typifies a forage with an RFV of 100.

RFV Example Calculation

Equations

DDM = 88.9 - (0.779 * %ADF)

DMI = 120 / %NDF

RFV = (DDM * DMI) / 1.29

Example (assume 35% ADF and 43% NDF)

DDM = 61.6%

DMI = 2.79%

RFV = 134

Use/Abuse of RFV

- **Used in hay marketing (buying and selling)**
- **Should be used to compare like forages**

Forage Quality Standards

Quality standards for legumes, legume-grass mixtures, and grasses.

Quality Standard	CP	ADF	NDF	RFV
	-------- % of DM --------			
Prime	>19	<31	<40	>151
1	17-19	31-35	40-46	151-125
2	14-16	36-40	47-53	124-103
3	11-13	41-42	54-60	102-87
4	8-10	43-45	61-65	86-75
5	<8	>45	>65	<75

Proposed Hay Testing Guidelines

Alfalfa and alfalfa/grass hay

Quality Standard	ADF % of DM	RFV
Supreme	< 27	> 180
Premium	27-30	150-180
Good	30-32	125-150
Fair	32-35	100-125
Low	> 35	< 100

Proposed Hay Testing Guidelines

Grass hay	
Quality Standard	**CP (%)**
Premium	> 13
Good	9-13
Fair	5-9
Low	< 5

Example Comparison of Old Standards and New Guidelines

	Alfalfa		
Quality meas.	Haylage	Hay	Limpograss
Moisture (%)	27.8	10.8	11.3
CP (%)	20.2	18.7	15.5
ADF (%)	57.5	30.7	37.1
NDF (%)	60.6	39.3	59.0
DDM (%)	44.0	65.0	60.0
DMI (%)	2.0	3.1	2.0
RFV	67	154	95
AFGC std.	Std. 5	Prime	Std. 3
New guide	Low	Premium	Premium

Hay Sampling Demonstration

Sampling

- **Representative Sample**
- **Results Only as Good as Sample**

What Was Examined:

- 7 ‘Lots’ of hay with a wide range of forage quality (smaller than normal, still ‘lots’)
- Within Bale Variation--how much is there?
- Does it matter how many cores are taken?
- Why not a grab sample?
- Why not just 2-3 cores?
- Why not mix hay lots

Hay Sampling Demonstration: 7 Hay Lots

- **Lot 1: 1999 Fourth Cut Excellent Quality 1,000 lb. Bales**
- **Lot 2: 1999 First Cut Rain-Damaged Hay 1,000 lb. bales**
- **Lot 3: 2000 First Cut Hay Excellent Quality 80 lb. bales**
- **Lot 4: 1999 Third Cut Medium Quality 80 lb. bales**
- **Lot 5: 2000 First Cut Good Quality 1,000 lb. bales**
- **Lot 6: 1999 Third Cut w/Bleach 1,000 lb. bales**
- **Lot 7: 2000 First Cut 700 lb. Round Bales**

Hay Sampling Demonstration: Crude Protein

Crude protein (%) determination using 20-, 3-, and 1-core samples or a grab sample from 7 hay lots.

Hay Lot	20 Cores	3 Cores	1 Core	Grab
1	21.6	21.5	22.0	20.0
2	20.4	21.5	22.2	17.0
3	18.9	19.9	20.4	17.6
4	19.0	20.8	19.7	19.0
5	19.4	18.7	18.5	15.5
6	20.1	21.5	21.8	17.3
7	19.9	18.9	19.1	15.1
Average	19.9	20.5	20.5	17.5

Hay Sampling Demonstration: ADF

Acid detergent fiber (%) determination using a 20-, 3-, or 1-core sample or a grab sample from 7 lots of hay.

Hay Lot	20 Cores	3 Cores	1 Core	Grab
1	22.5	23.8	23.5	25.9
2	42.7	41.4	42.4	47.5
3	31.9	31.0	30.7	34.1
4	38.3	36.5	36.1	37.4
5	30.6	29.1	32.5	34.2
6	35.2	34.1	33.3	37.9
7	36.3	36.8	36.7	42.1
Average	33.9	33.2	33.6	37.0

Hay Sampling Demonstration: NDF

Neutral detergent fiber (%) determination using a 20-, 3-, or 1-core sample or a grab sample from 7 hay lots.

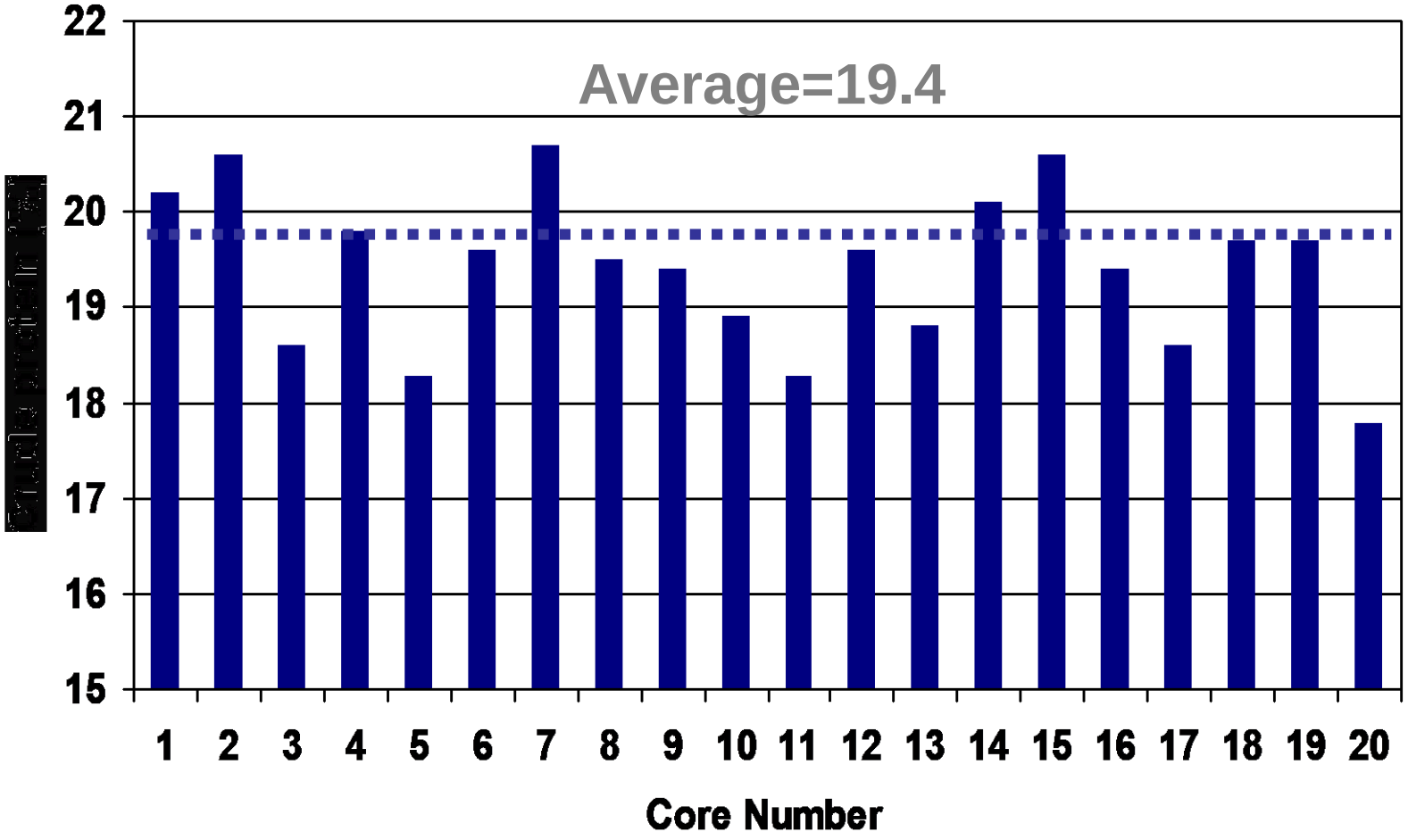
Hay Lot	20 Cores	3 Cores	1 Core	Grab
1	29.8	30.8	31.0	33.2
2	55.8	54.3	56.4	60.7
3	37.8	37.1	37.7	40.7
4	47.4	47.3	45.7	45.4
5	36.4	35.6	38.8	40.4
6	43.6	42.4	41.2	48.1
7	44.2	45.2	44.2	48.8
Average	42.1	41.8	42.1	45.3

Hay Sampling Demonstration: RFV

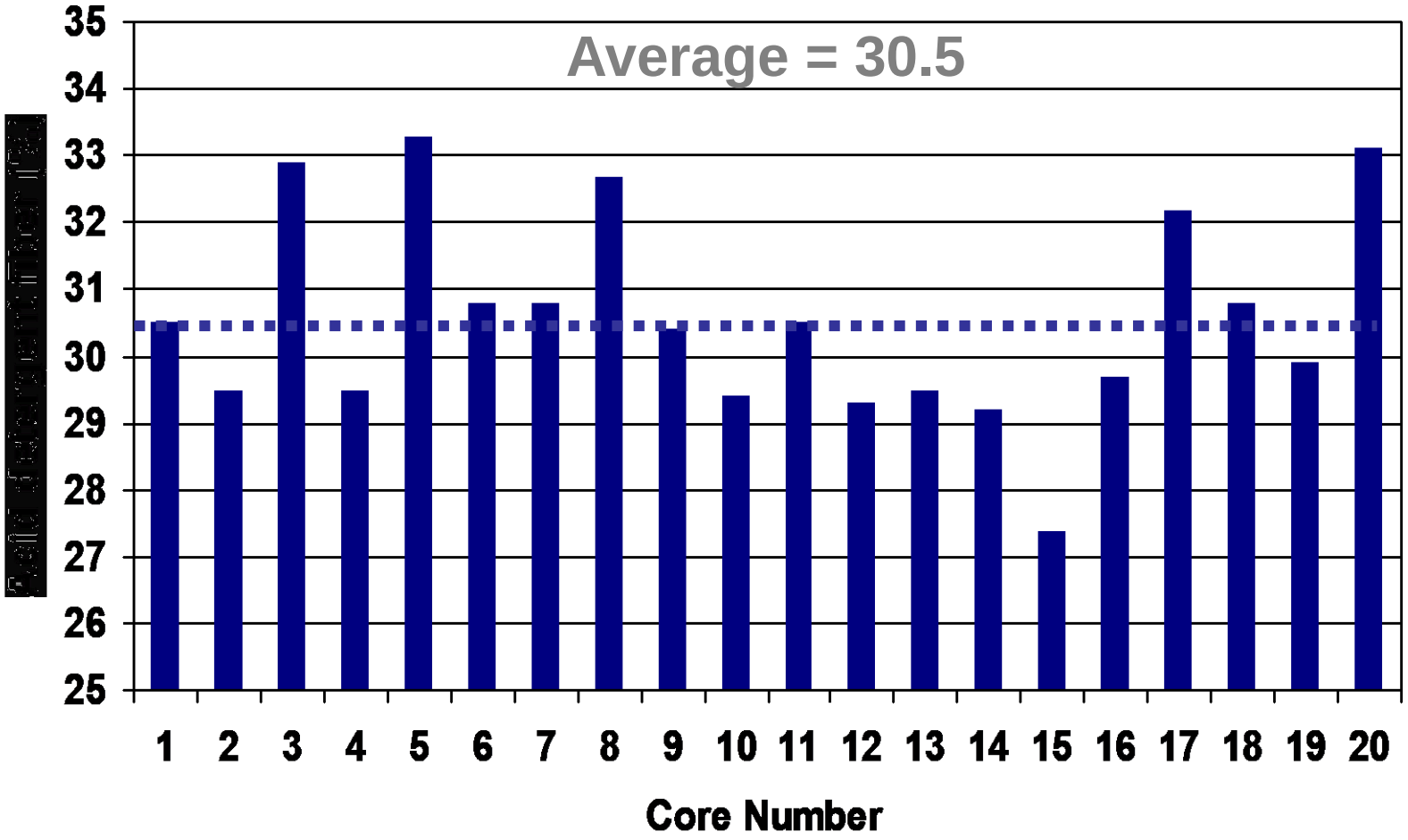
Relative feed value determination using a 20-, 3-, or 1-core sample or a grab sample from 7 hay lots.

Hay Lot	20 Cores	3 Cores	1 Core	Grab
1	223	213	212	192
2	93	97	92	80
3	158	163	160	143
4	116	119	124	123
5	167	173	153	143
6	131	137	142	115
7	128	124	127	107
Average	145	144	146	129

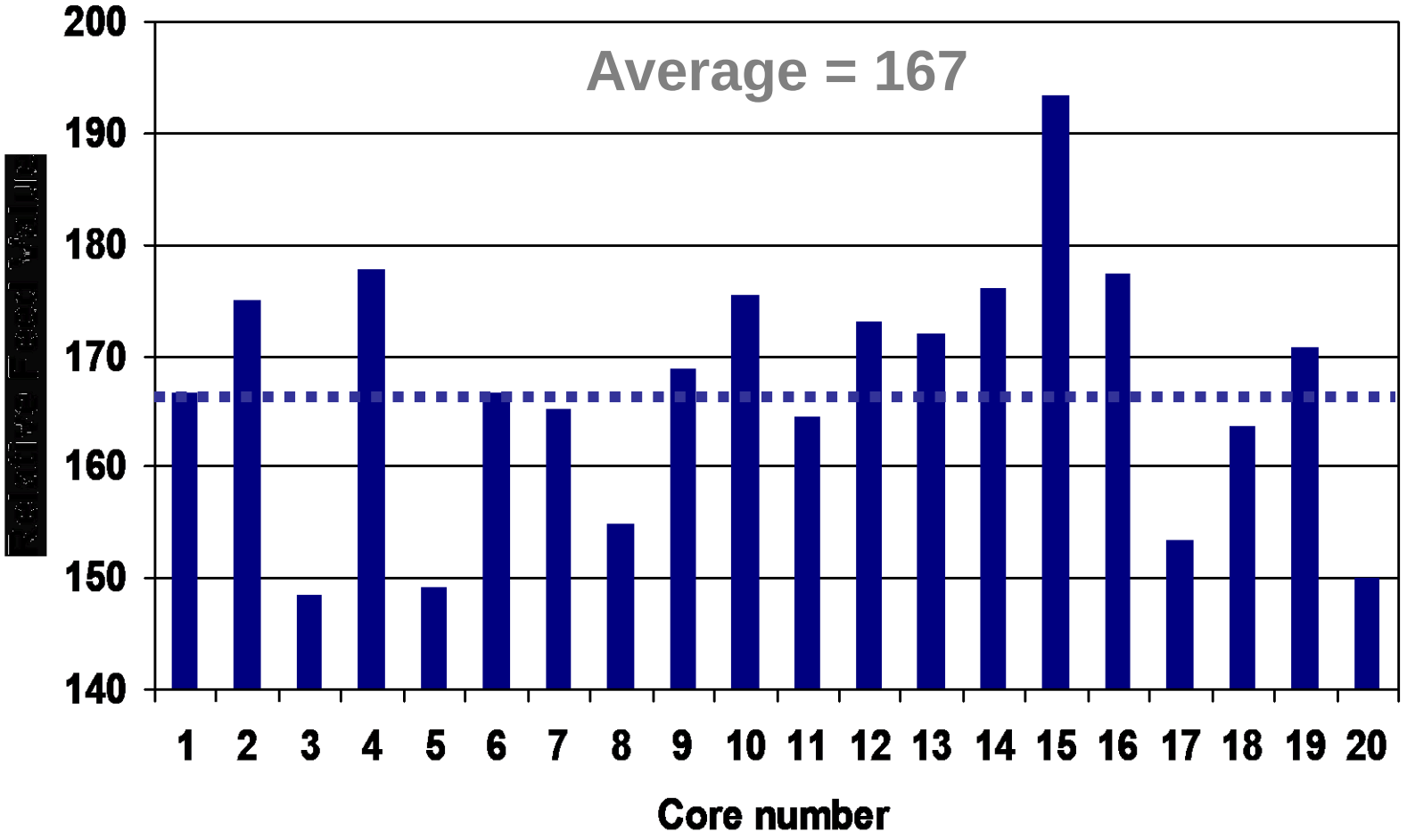
Variation in CP by core number--Lot 5



Variation in ADF by core number--Lot 5



Variation in RFV by core number--Lot 5



Sampling locations in large square bales

Standardized Sampling Guidelines

- **Identify a single lot of hay (<200 tons)**
- **Choose an appropriate, sharp coring device (3/8”-3/4” in diameter)**
- **Sample at random (don’t avoid bales)**
- **Take enough cores to represent a lot (at least 20)**
- **Use proper technique (90^{o} angle, 18”-24” deep)**
- **Handle samples correctly (plastic bags, heat)**
- **Appropriate size: not too big, not too small (1/2 lb)**
- **Only split samples after grinding if you want to test different labs**