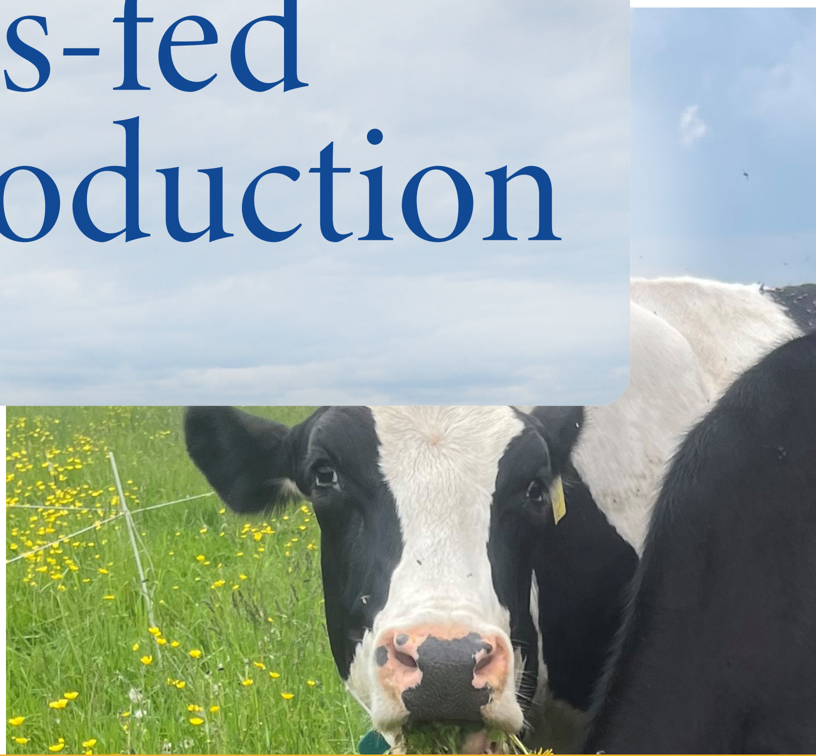



A Farmer's Guide TO Grass-fed Dairy Production

A PUBLICATION OF
THE UNIVERSITY OF VERMONT EXTENSION
NORTHWEST CROPS AND SOILS PROGRAM

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PUBLISHED BY
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NORTHWEST CROPS AND SOILS PROGRAM

Acknowledgments

This farmers' guide is published through University of Vermont Extension Northwest Crops and Soils Program in St. Albans, Vermont.

The resource could not have been created without the support of the United States Department of Agriculture's National Institute of Food and Agriculture, Northeast Sustainable Agriculture Research & Education program (LNE16-345), Organic Research Education Initiative (award 2018-51300-28515), Organic Valley's Farmers Advocating for Organic grant program, the Northeast Extension Risk Management Education program (grant 2015-49200-24225), and the Northeast Dairy Business Innovation Center (contract #45520).

Thank you to all the contributing authors and reviewers including Dr. Sidney Bosworth, Kurt Cotanch, Dr. Heather Darby, Sarah Flack, Dr. Sabrina Greenwood, Dr. Bryony Sands, Dr. Miriam Snider, Dr. Kathy Soder, Patrice Vincent, Julianna White, and Sara Ziegler. Thank you to all the farmers and other experts who contributed valuable insights and experiences.

Suggested citation:

University of Vermont Extension. (2023). A Farmer's Guide to Grass-fed Dairy Production. Burlington, Vermont: University of Vermont Extension. Available from: https://www.uvm.edu/extension/nwcrops/grass-fed-dairy

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CHAPTER ONE

Introduction

What is 100% Grass-fed Dairy?

As of 2023, there is no national definition of grass-fed. For the purposes of this publication, we define grass-fed milk according to generally accepted standards in use by the majority of farms and companies selling products indicating grass-fed on the label. Grass-fed milk comes from dairy animals fed a diet that does not contain grain; instead, the ration is a mixture of different types of forages (not just grass) including legumes, grasses, and forbs such as chicory, plantain, and dandelion. Grass-fed dairy animals can consume both annual and perennial forages as long as annual forages are consumed before they form seed (grain). For example, corn silage is not considered an acceptable forage. Supplementation with minerals and energy foods that do not contain grain or grain byproducts, such as molasses, are typically allowed. However, particular milk buyers may have additional restrictions related to energy supplements and other on-farm practices. In most cases, grain may not be fed to non-lactating young stock.

For the purposes of this publication, "grass-fed" is defined as "meeting all livestock nutrient needs with forages (fresh, ensiled, or dried) and where no grain or corn silage is fed."

History of Grass-fed Dairy

Historically, farmers relied on grazing forages to provide their animals with adequate nutrition for meat and milk production during the grazing season. However, with advances in technology and animal nutrition, dairy production in much of the developed world shifted away from grazing systems to indoor feeding systems that provided more control, efficiency, and higher production. This was the case in the U.S., where total mixed rations (TMRs) fueled by low concentrate costs became mainstream in the 1950s and 1960s. Despite this global trend towards confinement, some regions with climates and landscapes particularly suited for growing forages, such as New Zealand and Ireland, saw less benefit to adopting confinement systems and remained heavily reliant on grass-fed systems. In the 1980s and 1990s, interest in high-forage and grass-fed dairy production began to grow in the U.S. However, at that time there were not separate milk markets to distinguish grass-fed products from those derived from other production systems. Furthermore, the trend towards confinement had resulted in limited technical assistance for farmers continuing and converting to grass-fed systems. Therefore, while some farms adopted grass-fed systems, many found either the production system to be a poor fit for their cows and farm or the milk production to be too low to cover farm overhead costs.

This divergence in dairy production systems provided opportunities to learn about the impacts of grass-fed production systems on milk nutritional composition, flavor, and processing, the environment, and farm and dairy economics. For example, grass-fed milk has been shown to have higher levels of omega-3 fatty acids, lower ratios of omega-6:omega-3 fatty acids, and higher total conjugated linoleic acid (CLA) levels. These beneficial fats have been linked to reduced risk of cardiovascular and other metabolic diseases. Perennial grass-fed livestock production systems may also result in environmental benefits when compared with production systems that rely heavily on annual crop production, concentrated livestock feeding, and manure storage systems. Environmental benefits can include better water infiltration, reduced nutrient leaching, increased carbon sequestration, reduction of erosion, enhanced biodiversity, pollinator, and wildlife habitat.

To satisfy increasing consumer demand for grass-fed dairy products, several dairy processors launched product lines with milk produced from cows fed exclusively forages. Today, grass-fed is the most rapidly growing sector of the dairy industry. With more grass-fed dairy farms, common key factors contributing to the success of many of these farms are becoming better understood. This information is needed by farmers, service providers and processors to assure the sustainability of this market sector. See the end of this chapter for the results of a national survey of grass-fed dairy producers.

Grass-fed Dairy Production Standards

Unlike the word "organic," which is defined by the USDA National Organic Program's Organic Standards, USDA not yet established a definition of "grass-fed milk". However, there are now third-party grass-fed standards, and many certifiers now offer grass-fed certification. Currently, the two main grass-fed certification standards in the U.S. are administered by Organic Plus Trust Inc. and the American Grass-fed Association (Figure 1). More information regarding these standards is found at the end of this chapter.

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GRASS-FED

Grain, or grain by-products, cannot be fed, even in mineral supplements.

Minimum of 60% dry matter intake (DMI) from pasture during grazing-season.

150-day minimum grazing season length.

ORGANIC

Organic grain can be fed.

Minimum of 30% DMI from pasture during grazing season.

120-day minimum grazing season length

Figure 1: Comparison of Organic Plus Trust Grass-fed and USDA Organic standards.

Considerations, Challenges, and Strategies to Transition to Grass-fed Production

For many farmers, grass-fed dairy seems to be a potential "way forward" for producers who can adapt to this management system. With that said, grass-fed dairy as a production system can require significant changes in farm management and increases the cost of production for most producers. Thus, grass-fed dairy is not feasible for all producers. If not managed carefully, transitioning to grass-fed may lead to worse financial positions for farms despite potential premiums and may result in animal welfare issues. In addition to on-farm production challenges, there are market challenges related to balancing supply and demand for grass-fed milk within the currently stressed dairy market environment.

Removing grain from dairy rations and producing milk on 100% forage may sound straightforward, but the transition is complex. Most herds are composed of cows with genetics that prioritize milk production levels that cannot be supported by forages alone and may be less suitable to grazing. Therefore, to succeed in a grass-fed system, dairy farmers must be prepared to select the right herd genetics and characteristics; provide an adequate supply of high-quality forage and a balanced mineral supplement; and carefully monitor herd health, reproductive performance, and animal welfare. This may be a hefty challenge, but farmers who are able to simultaneously manage these aspects well are finding success.

In general, farms succeeding with grass-fed dairy production systems:

- Replace grain with a larger quantity of high-quality (high digestibility and high energy) forages,
- Increase acres of pasture and cropland per cow to meet higher forage intake needs,
- Pay more attention to soil health and fertility inputs as off-farm nutrients from grain are eliminated,
- Establish new mineral supplementation programs once cows are no longer able to receive required minerals and salt mixed with grain,
- Closely monitor body condition, reproductive performance, and other measures of livestock well-being,
- Select herd genetics that are better suited to high forage rations, and
- Adapt business plans to be sure the farm is still able to remain financially viable with lower milk production from the grass-fed herd.

Each of these critical management topics are discussed in detail in this manual.

Research Highlight: Grass-fed Dairy in the Northeast

Research of grass-fed dairy farms in the U.S. in recent years has begun to provide initial benchmarks for this industry. The data below were generated from 164 responses to a national survey sent in 2019 to just over 350 farms. Although the scope of the survey was national, the majority (63.4%) of respondents were located in the Northeast.

Farm Characteristics

Grass-fed farms manage an average herd size of 49 cows, though herds ranged in size from 2 to over 200 cows. Crossbreeds are most common (54.1%), followed by Holstein (21.7%) and Jersey (17.2%). Farms reported that they had been dairy farming for an average of 21 years, organic for an average of 10.3 years, and grass-fed for an average of 5.1 years.

Acreage, Crops, Pasture, Hay Production, and Fertility Inputs

Farms managed an average of 219 acres of pasture and cropland. In addition to perennial pasture and hay, 32% of farms also grew some annual forage crop. Despite managing 4.5 acres per cow, 63.9% of farms still needed to purchase an average of 38.3% of their total forage needs each year. This is higher than the 3–4 acres per cow typically seen on organic dairy farms that feed grain in this region. Data from a smaller subset of farms enrolled in a cost of production study found that farms were managing 5.5 acres per cow. Within that subset of farms, those producing 100% of their forage needs were managing 6.8 acres per mature cow.

Farmers reported that fertilizer, manure, or other off-farm soil amendments were "typically purchased" on 76.5% of farms. Poultry manure (62.2%) and lime (56.6%) were most common. Soil tests were utilized on 80.8% of responding farms, while forage and manure were tested on 43.1% and 17.4% of farms, respectively. Most farmers reported using a grazing system in which cows are moved to a new paddock two or more times per day for an average of 197 days a year. During the grazing season, 38.9% of farms report that their pastures provide over 90% of their total forage needs.

Replacements and Young Stock

Forty percent of farms were keeping all heifer calves, despite an average 16.2% cull rate reported. Calves were most commonly raised in group feeder systems (44.3%) and on individual bottles/buckets (44.3%). Calves were fed an average of 1.9 gallons of milk per day for an average of 4.9 months; however, some farms indicated they fed as much as 4 gallons per day per calf for up to 10 months. Data from a smaller subset of Northeast farms enrolled in a monthly benchmarking project showed that calves received average of 2.3 gallons of milk per day per calf. These data indicate that calf-rearing is a significant cost in lost potential milk income for many farms. In addition, calves add to the forage supply needed and may be part of why these farms average so many more acres per cow.

Milk Production

Most farms (84.8%) produced milk year-round and milk twice or more per day (84.9%). Average annual self-reported milk production was 9,305 lbs. per cow, but milk productions ranged from 1,100– 18,300 lbs. This is milk produced, not pounds shipped, which is lower since milk is used to raise youngstock. Average butterfat and protein content were 4.39% and 3.33%, respectively. Farms in the Northeast that provided data managed 55 cows producing 8,946 lbs./cow/year and raised an average of 12 calves.

Farmers who have recently converted to grass-fed shared anecdotal information that they had a reduction in milk production ranging from 20% to 45%; however, it appears there are additional significant changes in production depending on the time of year and the overall quality of forages made in any given growing season. Additional research is needed to determine the primary factors contributing to low milk production per cow on some farms. While genetic selection, forage quality and insufficient energy may be the limiting factor for many, on some farms it may be due to poor reproductive performance of the herd, resulting in extended calving intervals and days in milk.

KEY POINTS

- As of 2023, USDA had not established a definition for grass-fed milk.
- This publication defines "grass-fed" as "meeting all livestock nutrient needs with forages (fresh, ensiled, or dried) and where no grain or corn silage is fed."
- Grass-fed is the most rapidly growing sector of the dairy industry.
- Transition to a grass-fed production system is complex and can require significant changes across all aspects of farm management.

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CHAPTER TWO

Forage Management

Forages are the backbone of a grass-fed dairy production. There is enormous pressure on the farmer to produce not only the quantity but also the quality of feed that will sustain the herd's nutrient requirements throughout the year without sacrificing milk production, milk quality, and animal health. Forage quality and productivity can be, even with best management practices, highly variable. Therefore, careful planning and monitoring are key to minimizing fluctuations and their impacts.

Land Base and Forage Inventory

Farms that don't feed grain require a larger quantity of consistently high-quality forage. Depending on stage of production, cows will consume 1.75-4.5% of their body weight in dry matter per day. And depending on the fiber content of the forages, the cows will adjust their intake to maintain a constant fiber intake.

Therefore, grass-fed management may require a farm to increase purchased forage, increase forage yield per acre, or increase the total acreage for pasture and forage production. For this reason, a thorough assessment of the farm's land base lies at the heart of determining the carrying capacity of a grass-fed dairy operation. The pasture and stored forage capacity and quality must match animal numbers and milk production goals.

Important land base considerations include:

- Distribution—Sufficient grazeable land within proximity to the milking facility is necessary to meet the grazing season length and intake requirements of grass-fed certifications.
- Economics—Increasing the land base may not be more economical than purchasing feed.
- Soil fertility—Maintaining high forage productivity and quality on more acres will require increasing soil amendment costs.
- Seasonal demand—Depending on location, there may be a significant number of months during which all the herd's feed requirements must be met by stored forages.
- Intake and nutrition requirements—Many farmers continue to provide stored forages during the grazing season to ensure the cows have constant access to feed to meet their intake and nutrient requirements. Feeding forages with high fiber digestibility will increase the quantity of forage needed.

Initial research shows that, on average, grass-fed dairy farms in northern climates producing all their own forages (stored and pasture) use 6–7 total acres per cow. The number of acres needed can be reduced if higher forage yields and quality can be attained per acre or if high-quality feed is abundantly available and economical to purchase.

An important step in planning and evaluating a forage program is developing a forage inventory. While fairly simple for a confinement herd, determining quantity and quality of forage needed per animal group on the farm while grazing can be more challenging and likely will take careful observation and refinement.

Example: Forage Inventory Calculation

An example of a forage needs estimate and forage production inventory for 90 animals (60 cow grass-fed farm and 30 additional young stock) is below. For each animal group, the dry matter intake (DMI) needed is multiplied over the number of animals in the group and the number of days fed to generate a total of tons of dry matter (DM) per year needed to feed that group. An example calculation follows.

60 lactating cows x 42 lbs. DMI each x 305 days fed 2000 = 384 tons DM per year

By summing the annual need of each animal group including dry cows and youngstock, the herd requirement is 500 tons of DM/year (Table 1). This example assumes that each cow is dry for 60 days and her lactation is 305 days, and that there are 30 head of youngstock. If we then factor in a waste factor of 10%, a total of 550 tons of DM/year is needed.

If we then take stock of the acreage available on the farm of pasture and hay, producing 1.75- and 2.5-tons DM/acre respectively, the farm will produce a combined total of 373 tons of DM/year (Table 2). From this, we can see that this farm would be short 177 tons of dry matter each year. They would either need to purchase an additional 177 tons or would need some combination of increased pasture and/or hay yields and more land for gazing and haying to compensate for this shortcoming. Table 3 shows how DMI needs differ by size and bred.

Table 1. Dry matter intake needs.

Animal Group	No. Cows	BW, lbs	DMI, lbs.	DMI, %BW	Days Fed	Tons DM/Yr.
Lactation Cows	60	1200	42	2.5	305	384
Dry Cows	60	1200	24	2.0	60	43
Heifers Pregnant	15	800	18	2.3	365	49
Heifers Growing	10	400	10	2.5	365	18
Heifers Young	5	200	5	2.5	365	5
Total						500
With Waste Factor of 10%						550

Table 2. Dry matter from forage produced.

Forages Grown	Acres	DM T/A	DM T/yr.
Pasture	70	1.75	123
Hay Fields	100	2.5	250
Total			373
Net: Required/Grown			177 tons short

Table 3. Estimating DMI as % of body weight (BW) for large and small dairy cattle breeds.

	Growing			Pregnant and Dry		Lactating	
BW, kg	100	200	300	400	454	454	680
BW, lb.	220	440	660	880	1000	1000	1500
DMI, %BW	3.0	2.6	2.5	2.4	2.2	3.5-4.5	3.5-4.5

Source: NRC 2001

To determine the amount of pasture and stored feed needed, the farmer must:

1. Determine how much feed from pastures to include in the ration during the growing season.
2. Determine type, size, and total number of cows and total replacement animals from birth to calving.
3. Determine total number of acres available to the whole herd.
4. Determine realistic yields.
5. Account for realistic levels of harvest, grazing, or storage losses.

More information on monitoring DMI and the factors impacting it can be found in Chapter 4.

Assessing Forage Quality

Most forage analyses are conducted using near-infrared (NIR) spectroscopy to scan samples after drying and grinding and use algorithms to estimate nutrient content. NIR algorithms are based on the gold standard of "wet chemistry," or chemical methods of determining nutrients: moisture, crude protein (CP), amylase Neutral Detergent Fiber organic matter (aNDFom), sugar, starch, and fats. NIR is quite accurate for these nutrients but is less precise for minerals. Furthermore, NIR is quite accurate for common forage species but can be inaccurate for less common alternative forages that do not have a robust wet chemistry database backing it. At the bottom of the forage report, there is a statement indicating bold values from wet chemistry. There are no bolded values in this report, indicating that all values were derived from the NIR analysis. Also note there are various means of expressing the nutrient concentration as either a % of the total DM (far right column), or as a fraction of its parent nutrient (i.e., as % of CP or % of NDF or aNDFom).

Figure 2 is an example of a forage quality analysis report from wrapped first cut baleage. Although there are many numbers on this analysis that have value, this guide outlines steps to quickly assess a forage test and uses example numbers from **Figure 2**.

1. **DM%—**Is the DM% in the proper range for the forage type and storage system? Ideal ranges are silage 30–40%, baleage 50–65%, dry hay >85%.
2. **NDF as % of NDFom and % of DM—**NDF is the fiber that is insoluble in a neutral pH detergent extraction composed of cellulose, hemicellulose, and lignin. The same method using an acid detergent extraction process results in acid detergent fiber (ADF), which is composed of cellulose and lignin, along with tiny amounts of protein and ash. Both NDF and ADF contain a portion of minerals, either inherent in the fiber or from soil contamination. Analysis of this residual mineral or ash allows for expression of fiber on an organic-matter-only basis, typically expressed as NDFom. Standard analyses of NDF also include the use of amylase to solubilize any residual starch compounds associated with fiber, thus resulting in aNDFom being the most accurate expression of NDF in feeds and forages. In Figure 2 under fiber and aNDF, note the slight difference of 45.2 in NDFom %DM and 45.9 in %DM; this indicates the proportion of inherent ash/mineral in the NDF. Less than a 2% difference is acceptable.
3. **NDF Digestibility 30hr on NDFom basis—**The data shows how much of the NDF is digestible in 30 hours. Generally, > 65% is good, and > 70% is better, while < 55% is poor and indicates low fiber digestibility (less energy and more rumen-fill limiting). The 74.3% reported here is excellent.
4. **uNDF 240 of the NDFom on % DM basis—**This indicates what percent of the total forage DM is indigestible NDF. Less than 10% is a good benchmark; the 6.0% here is excellent.

5. **Sugar: Ethanol-soluble carbohydrate (ESC) vs. water-soluble carbohydrate (WSC)**—ESC accounts for true sugars such as sucrose, fructose, glucose, etc. Grasses can have large amounts of fructans which are highly degradable WSCs that provide lots of energy. Over 15% is common on fresh grasses.
6. **Starch**—There are starch-like compounds in grasses, but not true starch (amylose compounds) of grains like corn.
7. **Crude Fat**—Crude fat is measured using total ether-soluble compounds, which include lots of indigestible pigments, waxy cutins, etc.
8. **Fatty acids make up 40-70% of the ether extract (EE)**. In **Figure 2**, this amount is 46.4%. Just above the fatty acids measure, note that 1.18% of total DM is rumen unsaturated fatty acids (RUFAL). Although this is a low percent of DM, depending on how much grass is consumed, a significant load of RUFAL in the rumen can cause milk fat depression.
9. **Ash**—The percent ash should be < 8% for grasses and < 11% for legumes. Levels > 8% in grasses or > 11% in legumes indicate likely soil contamination from harvest and can impact digestion.
10. **Minerals**—Farmers should ask for wet chemistry to be performed for more accurate mineral content. Adequate supply of minerals of grass-only rations is critical, and forage mineral content is not measured accurately via NIR procedures.
11. **Fermentation analyses**—Described in the qualitative section, fermentation analyses can help identify the good from the bad and the ugly. Baleage pH should be as low as possible, as the low pH inhibits growth of undesirable microorganisms such as clostridia, listeria, etc. The pH should be < 5.5, with lactic acid about 75% of the total and in a 3:1 ratio with acetic. Butyric should be < 0.25. Butyric acid is responsible for the putrid smell in poorly fermented silage and is also an indicator of much worse antinutritional compounds; zero butyric acid is ideal. It typically results from fermentation of wet (<28% DM) high CP (>18%) forages.

See **chapter 4 f**or more information on grass-fed dairy nutrition and balancing all-grass rations.

Figure 2. Example forage analysis report from wrapped first-cut baleage.

Source: Kurt Cotanch, Barn Swallow Consulting

FRESH 1ST CUT MAY 15

SAMPLE INFORMATION			
Lab ID:	30475 344	Version:	1.0
Crop Year:	2021	Series:	
Feed Type:	LEGUME FORAGE	Cutting#:	1
Package:	BASIC NIR		

NIR ANALYSIS RESULTS	
Moisture	41.5
Dry Matter	58.5

PROTEINS	% SP	% CP	% DM
Crude Protein			17.8
Adjusted Protein			17.8
Soluble Protein		37.4	6.7
Ammonia (CPE)	7.1	2.6	0.47
ADF Protein (ADICP)		5.4	0.96
NDF Protein (NDICP)		21.9	3.90
NDR Protein (NDRCP)			
Rumen Degr. Protein		68.7	12.2
Amino Acid Protein, Total		72.8	12.94

FIBER	%NDFom	NDFom %DM	% NDF	% DM
ADF			58.9	27.1
aNDF		45.2		45.9
NDR (NDF w/o sulfite)				
Crude Fiber				
Lignin			6.58	3.02
NDF Digestibility (12 hr)	50.6	22.9	50.5	23.3
NDF Digestibility (24 hr)				
NDF Digestibility (30 hr)	74.3	33.6	73.7	33.8
NDF Digestibility (72 hr)				
NDF Digestibility (120 hr)	82.9	37.5	82.2	37.7
NDF Digestibility (240 hr)	86.6	39.2	85.7	39.4
uNDF (12 hr)	49.4	22.3		
uNDF (30 hr)	25.8	11.6	26.3	12.1
uNDF (120 hr)	17.1	7.7	17.8	8.2
uNDF (240 hr)	13.4	6.0	14.3	6.5

CARBOHYDRATES	% Starch	% NFC	% DM
Silage Acids		5.9	1.7
Ethanol Soluble CHO (ESC-Sugar)		45.0	13.2
Water Soluble CHO (WSC-Sugar)			15.8
Starch		4.4	1.3
Soluble Starch			
Soluble Fiber		38.1	11.2
Starch Dig. (7 hr, 4 mm)			
Crude Fat			3.73
Fatty Acids, Total			1.73
C16:0			0.34
C18:0			0.02
C18:1			0.06
C18:2			0.34
C18:3			0.78
Unsaturated Fatty Acids (RUFAL)			1.18
Fatty Acids (%Fat)			46.4

Values in bold were analyzed by wet chemistry methods.

MINERALS	
Ash (%DM)	7.07
Calcium (%DM)	0.56
Phosphorus (%DM)	0.31
Magnesium (%DM)	0.21
Potassium (%DM)	2.32
Sulfur (%DM)	0.28
Sodium (%DM)	
Chloride (%DM)	
Iron (PPM)	
Manganese (PPM)	
Zinc (PPM)	
Copper (PPM)	
Molybdenum (PPM)	

QUALITATIVE	
pH	5.82
Total VFA (%DM)	1.74
Lactic Acid (%DM)	1.26
Lactic as % of Total VFA	72
Acetic Acid (%DM)	0.27
Butyric Acid (%DM)	0.21
1, 2 Propanediol (%DM)	
Nitrate Ion (%DM)	
Nitrate-Nitrogen, ppm	
Soil Contamination Probability	Probable low to none
NIR Statistical Confidence	Good prediction potential

ENERGY & INDEX CALCULATIONS	
TDN (%DM)	68.8
Net Energy Lactation (Mcal/lb)	0.71
Net Energy Maintenance (Mcal/lb)	0.77
Net Energy Gain (Mcal/lb)	0.50
ME (Mcal/lb)	1.19
AA Protein as % of Total Protein	72.8
NDF Dig. Rate (Kd, %HR, Van Amburgh, Lignin*2.4)	5.95
NDF Dig. Rate (Kd, %HR, uNDF)	5.5
Starch Dig. Rate (Kd, %HR, Mertens)	
Relative Feed Value (RFV)	138
Relative Forage Quality (RFQ)	192
Milk per Ton (lbs/ton)	3563
Dig. Organic Matter Index (lbs/ton)	950
Non Fiber Carbohydrates (%DM)	29.4
Non Structural Carbohydrates, ESC (%DM)	14.5
Non Structural Carbohydrates, WSC (%DM)	17.1
DCAD (meq/100gdm)	
Summative Index % (Mass Balance)	100.9

Additional sample information, submitted documents and lab pictures linked to QR code

Managing the Quality of Stored and Grazed Forages

High-quality forage should contain adequate nutrition (including protein, energy, minerals, and vitamins), be highly digestible, and be palatable. The following list of practices—developed from conversations with farmers, observations, and research findings—may help farms manage for consistent high-quality forage.

Develop a high-quality forage program by starting with soil.

Forage crops have higher yields, better quality, and more nutrition when grown on high quality soils. A soil test can help determine if soil fertility is adequate for growing a diverse array of forages. Soil pH should be between 6.5 to 6.8 for optimal legume, grass, and forb growth. Potassium, magnesium, and nitrogen are nutrients needed in large quantities by forages, but micronutrients are necessary as well. Avoiding compaction and building organic matter can help provide nutrients and excellent growing conditions. More information on soil management is found in chapter 3.

Choose the right species mixtures.

Almost all cool season forages can be managed to be of high quality, so it is important to match the right forage to soil, climate, and harvest system. Grasses and small grain forages have the highest potential to provide digestible NDF (NDFD). Figure 3 from Cumberland Valley Analytical Services laboratory summarizes the NDFD30, which is the percent of NDF digested in 30 hours of fermentation, across forage species. Note that grass and small grain silage have the potential of >70% NDFD30. Managing pastures

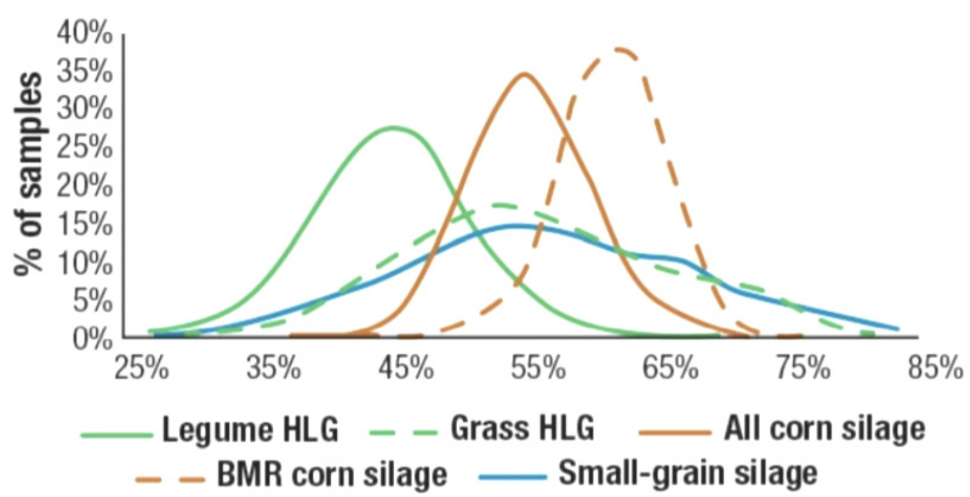

Figure 3. NDF digestibility of forages in 30 hours.
Source: Cumberland Valley Analytical Services, 2016

and harvestable hay and baleage to provide year-round supply of forages with NDFD >65% is possible.

A grass-legume species mixture usually broadens the "window" of harvest time while still assuring good quality. See Table 4 and Table 5 for pros and cons of forage legume species and perennial grass species. When grazing more mature grasses, cows alter their grazing behavior and prioritize dew-filled grass at dawn and dusk and eat easier-to-chew legumes the rest of the day. If legumes are not available, cows will lower their intake, which can lead to insufficient nutrient intake to maintain healthy lactating cows. Mixtures also help decrease the risk of crop failure and, since legumes fix atmospheric nitrogen, can reduce the need for nitrogen fertilization (a very costly amendment for farms). However, it is also important to recognize that legumes require higher quantities of potassium, sulfur, and boron as compared to grasses and therefore legumes may require changes to farms' soil fertility programs. Legume forages also typically contain higher levels of potassium, which can present health challenges such as milk fever if not managed properly.

Table 4. Pros and cons of forage legume species.
Source: Sid Bosworth, UVM Extension

SPECIES	PROS	CONS
Alfalfa	Greatest yield potential Maintains quality longer	Does not tolerate poorly-drained soils Less adapted to grazing
Red Clover	Yields well Tolerates a variety of soil conditions	Only persists for 2-3 years Can cause bloat
White Clover	Better adapted to grazing	Lower yielding Less drought tolerant Can cause bloat
Birdsfoot Trefoil	Matures later Tolerates poorly-drained soils Does not cause bloat	Lower yielding

Table 5. Pros and cons of cool season perennial grass species.
Source: Sid Bosworth, UVM Extension

SPECIES	PROS	CONS
Orchardgrass	High Yielding	Aggressively competes with legumes Tends to mature very early; select later maturing varieties to avoid harvesting or grazing low-quality forage
Meadow Fescue	High Fiber digestibility Tolerates a wide range of soil conditions Very compatible with legumes	Not tolerant of warmer climates
Tall Fescue	Very high yield potential Tolerates a wide range of soil conditions	Aggressively competes with other species Can present palatability issues when grazing; consider using "soft leaf" and novel endophyte varieties
Perennial Ryegrass	High digestibility and sugar tolerant	Less cold tolerant limiting persistence in some climates; consider using it in combination with other grasses and legumes

In addition to the grasses in the tables above, timothy and bromegrass cannot be cut early enough to achieve a level of quality suitable for high-producing dairy cows without greatly stressing the stand and causing early decline. However, there are newer varieties of timothy that may have more tolerance to early cuts.

Forbs are other plants to consider, especially in pasture mixtures. These non-legume and non-grass species include plants such as forage chicory and plantain, among others. When purchasing seed, check with the local seed company for suitability for region and soils. Also, buy certified seed from a reputable dealer. Avoid "common" named varieties when possible. With common seed, there is no information on productivity, adaptability, or pest resistance. In addition, common seed grass varieties often mature early. (If the seed tag does not give a named variety for a particular forage species, then it is considered common.)

Cutting management is critical to achieve high-quality stored forage.

Focus on the first two harvests of the year. Research has shown that the first and second cuttings have the highest potential for producing the most digestible forage and, therefore, have the highest level of energy (Figure 4) due to the optimal conditions for cool-season grass and legume growth and quality during spring and early summer. A timely first harvest "sets" the timing for the rest of the season. Ideally, two cuttings will be made before the summer solstice in the northern regions of the U.S., maximizing yield of digestible fiber. **Figure 4** shows the highest potential in the first cut and little difference in quality between the second and third cuts.

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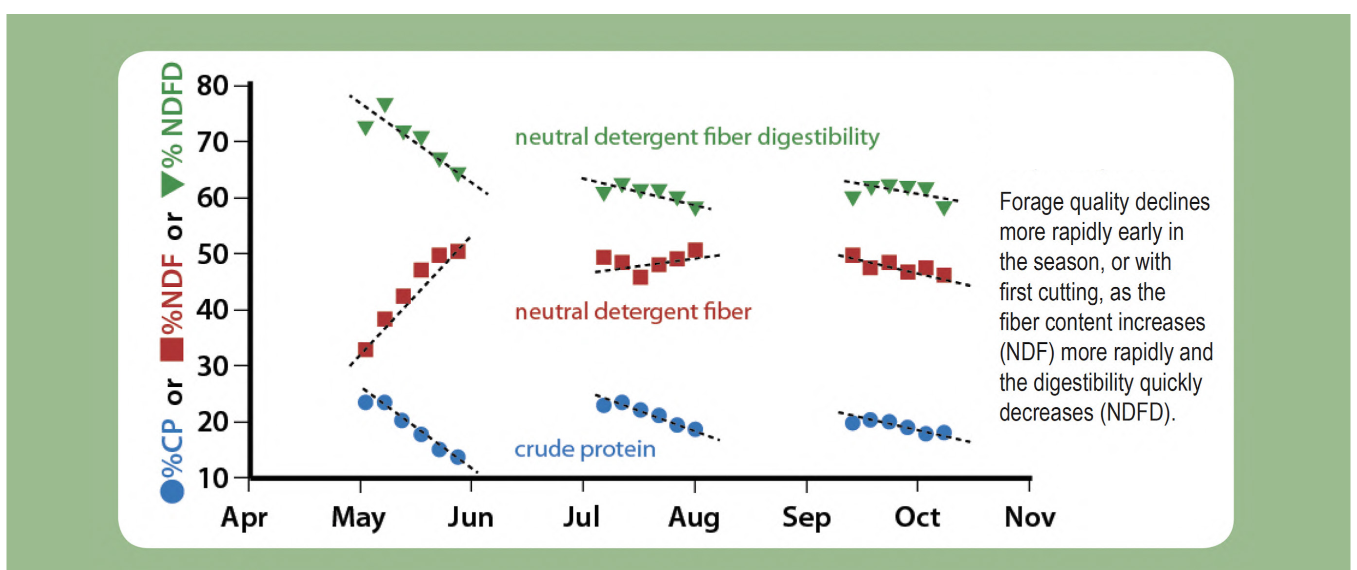
Figure 4. Perennial grass forage quality throughout the growing season.

Source: Team Forage, University of Wisconsin Extension



Maturity is the main driver of forage quality. For grasses, the first cut should be early, or in the pre-boot stage, for lactating animals (Figure 5). By late-boot to head-emergence stages, digestible fiber is too low to be considered desirable for lactating cows. High temperatures also result in greater lignification of the cell wall, resulting in lower digestible forage.

Unfortunately, first cut hay in northern climates is often the poorest quality due to delayed harvests (mid-late June in the northern U.S.) often caused by uncooperative weather. Therefore, it is important to design a forage program that increases the chances of making a timely first harvest. Being prepared with well-maintained equipment ready to go is critical. If the farm does not have adequate equipment ready when the forage is ready and is therefore unable to move quickly, farmers should consider utilizing custom operators who may be able to harvest more quickly. The savings in quality may be worth the additional cost and can free up time to focus on other aspects of the operation.

Farmers should plan to make the second cut within 30–35 days of the first cut, depending on particular forage and growing conditions. If there is a hot, dry, or excessively rainy spell during this period, the forage quality may drop below what is appropriate for lactating animals.

Design a flexible forage production program and forage inventory.

A land base that is 20% larger than what is needed provides the flexibility to work with variable weather conditions. If spring and early summer conditions are good, it may be possible to achieve most high-quality forage needs in the first two cuttings. This would allow later cuttings to be somewhat delayed. Delaying the cutting frequency of the third and/or fourth harvest can strengthen the forage stand by encouraging a buildup of energy reserves in the roots while maintaining quality suitable for late lactation cows, dry cows, or heifers. Alternatively, if the first cut is delayed due to poor spring weather, then the second and third cuttings should be targeted for higher quality.

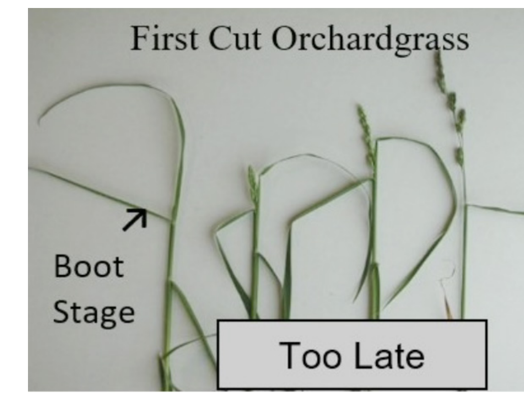


Figure 5. Target growth stage to harvest grasses.

Source: Sid Bosworth, UVM Extension

A flexible system also allows allocation of forages to the appropriate animal groups according to quality. The best system for any given farm will vary and be dependent on farm size, labor availability, soil type, types of crops, and whether the farm uses custom harvesting. This also requires testing forages to better determine feed allocation to various animal groups. Generally, the best grass forage will have a NDF content of 45 to 50%, and a legume/grass mixture should be no higher than 45% NDF. Usually, feed forages that are over 55% NDF should not be fed to the most productive lactating animals. For good milk production, NDF digestibility (30-hour fermentation) should be over 60% of NDF. Second and third cut forage may look good (for example, leafy), but they may be less digestible (due to higher lignin content) if grown under hot, dry conditions. The best quality forages come with sunny but cool temperatures; adequate, but not too much, moisture; adequate fertility; and proper cutting. Table 6 shows target quality parameters for lactating and dry cows and replacement heifers to maintain adequate production and growth, and Table 7 shows forage quality goals by forage type.

Animal Group	% Protein	% NDF	% NDFd30h	NE_L, Mcal/lb.	NE_G, Mcal/lb.
Lactation	16-18	<55	>75	>0.80	
Dry Cow	14-16	55-60	>50	0.58-0.62	
Heifers Pregnant	14-16	55-60	>60	>0.75	>0.56
Heifers Growing	18-20	<55	>65	>0,78	>0.60

Table 6. Nutrition goals by animal group.

Forage	% DM	% Protein	% NDF	% NDFd30h	NEL, Mcal/lb.	% NFC	% ADF
Dry Hay*/Mixed Legume	>85	13-18	50-55	>60	0.52-0.61	15-20	35-40
Dry Hay (Alfalfa)	>85	18-22	42-47	>50	0.55-0.58	22-25	33-35
Grass/Legume**	50-65	16-18	40-50	>60	0.49-0.58	18-22	32-38
Alfalfa Haylage/Bale	50-65	21-23	37-45	>50	0.55-0.61	22-28	30-35
Managed Pasture***		>25	45	>70	0.68	17	25
Managed Pasture: ****		>20	50	>70	0.64	15	30

Table 7. Forage quality goals by forage type.

Source: Adapted from Hoffman, K., 2018

* Dry Hay (grass)/Mixed Legume
** Grass/Legume Haylage or baleage
*** Spring and Fall
****Summer

Consider incorporating annual forages into the rotation.

Annual forages such as sorghum-sudan grass, sudan grass, millet, teff, small grains, and brassica crops can help provide flexibility in meeting production and quality needs throughout the season. Small grains such as oats, cereal rye, and wheat produce ample forage and are more productive than perennial forages during cool weather. Summer annual grasses such as sorghum, sudan grass and millet thrive under the hot conditions of mid-summer months when perennial forage species do not. Most of these annuals can be pastured or harvested as silage or hay. However, under most grass-fed dairy production standards, these crops must be grazed/harvested prior to grain head production. This can present management challenges as these crops can grow and mature very quickly under optimal growing conditions. Including these crops into rotations can also allow farmers to incorporate needed lime, manure, and other amendments to soils and help break some insect and disease cycles. As seed and seedbed preparation costs can be substantial, annuals are more commonly utilized prior to reseeding a field to perennials. If using annual forages for a lactating herd, consider high-quality traits such as BMR (brown mid-rib) available for some varieties of sudan grass, sorghum, and millet. BMR varieties have lower lignin content and thus higher fiber digestibility. It should be noted that some of these forages present unique management considerations to avoid animal health risks including nitrate and prussic acid toxicities. Informational resources on these topics can be found at the end of this chapter.

Plan to harvest most of forage as haylage and baleage.

The key to preserving forage quality is being quick. It is ideal to make silage in a day. If possible, mow early on a sunny, dry day and spread out the forage (wide swath) to maximize drying and minimize time in the field. The longer forages sit in the field, the more sugar they lose due to respiration, and beneficial fatty acids can be degraded. If possible, cut hay after a couple of good, sunny days to take advantage of high photosynthetic rates that promote sugar production. However, don't lose out on potential quality by waiting for the perfect day or time. Cut when the forage is ready, not when the weather is ready.

The goal of silage fermentation is to convert carbohydrates (mainly sugars and starch) to lactic acid to reduce pH to as close as 4 as possible. This process effectively "pickles" the forage to minimize loss of sugars, maintain protein quality, and prevent decomposition. The process relies on anaerobic bacteria, which are bacteria that thrive in an oxygen-free environment. Therefore, removing as much air from the silage mass as possible is critical to producing high-quality silage. The aerobic, or oxygen-loving, microorganisms that live on plants and soil surfaces are responsible for the degradation of feed. However, these organisms do not tolerate anaerobic or acidic conditions. Therefore, attaining these conditions can prevent such spoilage and help maintain a forage quality close to that of fresh pasture through the winter months to support healthy, productive animals.

Plant respiration, moisture, and packing are the most important factors in removing oxygen. Young plants maintain a higher respiratory rate longer and can contribute significantly to the reduction of oxygen in the silage mass. Moisture is very important for the development of the anaerobic lactic acid-producing bacteria that are beneficial during the fermentation process. Adequate moisture levels will proliferate these bacteria quickly, so the pH can drop very rapidly. Moisture will also help "lock" the material into place during packing and help compress particles against each other more efficiently. Packing is key to remove air pockets is the silage mass. Regardless of the storage method (baleage, upright silo, bunker, or pile), the key is to get the densest material possible.

Sufficient moisture is needed for complete fermentation in forages. Ideally, forages should be harvested between 35%–45% dry matter content (55–65% moisture). If the material is too wet, more acids are needed to achieve a pH level of 4. There is a risk that the carbohydrate reserves will be used up before enough acid is produced. This provides an opportunity for clostridial bacteria to take over the fermentation process. Clostridial bacteria break down protein into amine compounds and ammonia and support butyric fermentation, all which give the haylage a putrid smell and reduce nutritional quality. Cow health and production will suffer if they eat a significant amount of poorly fermented haylage.

If haylage is too dry (< 55% moisture), development of microbial populations responsible for lactic acid production and pH reduction will be slowed, risking an incomplete fermentation. Drier silage also means more air will be trapped in the material and can promote development of aerobic bacteria, yeasts, and molds. These microorganisms reduce feed quality by utilizing sugars, breaking down protein, and altering the integrity of the fiber. It is not uncommon to see the presence of molds in drier silage. Molds can sometimes produce mycotoxins that will challenge the immunity of animals. Several methods exist for determining the moisture content of forage that range from experience feeling the forage to drying and weighing in an oven or microwave. See the resources at the end of this chapter for more detailed information.

Good silage fermentation requires adequate levels of plant sugars to feed lactic acid bacteria in an oxygen-free environment. This can be achieved with proper management, including:

- Wilt to the proper moisture content as quickly as possible.
- Chop or bale as quickly as possible.
- Pack or bale tightly to minimize air.
- Use an inoculant when needed.
- Cover or wrap as quickly as possible with quality plastic.
- Allow enough time for the forage to properly and completely ferment before feeding: 2-6 weeks for haylage, 6-8 weeks for baleage.

If planning to feed dry hay to lactating cows, farmers must cut forages that are still in their vegetative stage, as is traditionally done with haylage. To dry hay properly, a lot of sunshine and heat are needed. In northern climates, the best time to make high-quality dry hay is from late June to early August. This hay will be leafier, characterized by smaller stems, and will be easier to dry down. Carbohydrate content in dry hay is usually high because development of microorganisms that could consume carbohydrates is prevented. Protein quality stays high unless there is excessive damage from harvesting when too wet. Dry hay should be 15% moisture or less in small bales and 10% moisture or less in big bales.

Maintaining Forage Stands

Maximizing the longevity of forage stands requires continual monitoring of soil fertility, compaction, and forage species composition. These factors influence yield and quality and continue to change over the life of the stand. Information about nutrient requirements of forages can be found in Chapter 3.

Compaction

Compaction can be an issue in hayfields and pastures, especially on poorly drained soils, as soil surfaces repeatedly have heavy machinery and animals running over them. Compaction leads to improper soil drainage which, in turn, reduces microbial activity and nutrient cycling while increasing the likelihood of runoff and poor plant quality and productivity. For more information on soil compaction, see chapter 3.

Species Composition and Stand Density

Monitoring species composition and stand density is a critical component of forage management. Forage stands should contain a diversity of species including grasses, legumes, and forbs that provide adequate nutrition to animals and maximize plant density. Dense stands in a pasture or hay field capture more available sunlight and therefore are more productive. Dense stands also offer more protection to the soil so that shade slows how quickly soil dries out in hot dry weather; conversely, in heavy rains water reaches the soil surface with less velocity and infiltrates better in dense stands. Dense stands also make it harder for new weed plants to germinate and establish. Since cows are limited by the number of bites they can take each day and the amount of time they can spend grazing, grazing dense pastures allows them to maximize intake per bite.

If changing management systems does not improve pastures and hay fields, other options include to introduce new seed into existing pasture or to completely reseed the field.

Frost seeding is a relatively low-cost option that slowly introduces new species or re-establishes short- lived perennial species.

Figure 6. ATV-mounted spin seeder.
Photo credit: Sid Bosworth

Species composition and density can change due to grazing/harvest management. If hay or pasture stands are thinning or do not contain desired species, consider altering management systems first, for example through extending rest periods, modifying stocking density, etc. See the resource list at the end of this chapter for monitoring tools that can help fine tune field and grazing management.

Seeding and Replanting Forages in Pastures and Hay Fields

If changing management systems does not improve pastures and hay fields, other options include to introduce new seed into existing pasture or to completely reseed the field. Additionally, in some situations improving a hay field can be done by changing mower height and cutting schedule or by frost, trample, or no-till seeding new species or reseeding.

Frost Seeding

Frost seeding is a relatively low-cost option that slowly introduces new species or re-establishes short-lived perennial species such as red clover. Do not expect to see a lush, new seeding the first year after frost seeding; it may take a couple seasons as the species establish to notice the impact. Frost seeding is typically done on established sod in late winter or early spring when the ground is experiencing freeze-thaw cycles between night and day. The freezing and thawing will create cracks in the soil surface through which the seed can move down into the soil to germinate. When seeding into an established sod, it is most successful on fields with some exposed soil and on fields that have been grazed or mowed short. Seed can be broadcast using a tractor- or ATV-mounted seeder or with hand-held seeders (Figure 6).

Frost seeding works best with legumes such as red and white clover. Red clover, a short-lived legume, can be increased and maintained for a relatively low cost in pastures and hay fields with regular frost seeding. Alfalfa and birdsfoot trefoil are slow to establish and are not as suited to frost seeding. Grass species that can germinate quickly in cold weather may also be frost seeded with some success. Perennial ryegrass is suited to frost seeding; however, winter hardy varieties must be used in many northern areas, and winterkill may require frequent seeding. A common approach to frost seeding is to do a section of the farm every year. This

Frost Seeding	Seeding rate (lbs. per acre)	
Species	Seeding Alone	In a Mixture
Alfalfa	5-8	3-4
Alsike Clover	2-4	1-2
Birdsfoot Trefoil	4-6	2-3
Ladino Clover	2-3	1-2
Meadow Fescue	6-8	3-4
Orchardgrass	3-4	1-2
Perennial/Italian Ryegrass	8-10	2-3
Red Clover	4-8	3-4
Reed Canary Grass	Not Recommended	
Smooth Bromegrass	Not Recommended	
Tall Fescue	6-8	3-4
Timothy	Not Recommended	

Table 8. Seeding rates for frost seeding into established sod.

Source: Adapted from Rankin, M. 2014

No-till Seeding	Seeding rate (lbs. per acre)*	
Species	Seeding Alone	In a Mixture
Alfalfa	12-15	8-10
Alsike Clover	Not Recommended	2-5
Birdsfoot Trefoil	8-10	2-6
Kentucky Bluegrass	12-14	4-6
Meadow Fescue	12-14	6-12
Orchardgrass	10-12	3-5
Red Clover	10-12	2-6
Reed Canary Grass	6-8	5-6
Smooth Bromegrass	15-18	6-8
Tall Fescue	12-14	6-12
Timothy	8-10	2-8

Table 9. No-till seeding rates for grass and legumes.

Source: Sid Bosworth, UVM Extension

When soil conditions are appropriate, graze the paddock to remove enough biomass that the seed can reach the ground when broadcast.

keeps the cost low but works to improve yield, quality, diversity, and density of all fields over time. Table 8 lists recommended species and seeding rates for frost seeding. More information can be found in the resource listing at the end of this chapter.

Trample Seeding

Trample seeding resembles frost seeding except the freeze-thaw action of frost seeding is replaced with animal hoof action to move the seed into contact with the soil for germination. Like frost seeding, this method works best with hard-seeded species such as clovers but can work with grasses as well. This method works best in pastures which are lower in plant density and have some exposed soil. The soil needs to be moist at the time of seeding to increase establishment success. However, if the soil is too wet, animal hooves may damage the soil or push the seed down too deep. When soil conditions are appropriate, graze the paddock to remove enough biomass that the seed can reach the ground when broadcast. Broadcast the seed and allow the cattle to finish grazing the paddock to work the seed into the soil. Remove the animals from the paddock after the seed is trampled but before they germinate. To avoid damaging newly germinated plants, animals should not graze the paddock until it has fully recovered. Frost seeding rates should be used (Table 8).

Figure 7. No-till drill.

Photo credit: Susan Brouillette

Furthermore, it is important to time no-till seeding when the soil is moist enough to encourage germination but not so wet so that the equipment causes compaction. It is also critical to properly calibrate the drill and to monitor seeding depth during planting, adjusting as necessary

No-till Seeding

A no-till drill (*Figure 7, opposite page*) can be used to interseed in established pastures and hayfields or reseed a field to reduce risk of erosion. The increased seed-to-soil contact that a drill provides increases the success of seeding into established sod as compared to frost seeding, but no-till seeding is a more costly option.

Furthermore, it is important to time no-till seeding when the soil is moist enough to encourage germination but not so wet so that the equipment causes compaction. It is also critical to properly calibrate the drill and to monitor seeding depth during planting, adjusting as necessary. Even if this takes more time, it is crucial to good establishment. Interseeding with a no-till drill should be done in the spring, as with frost seeding. However, the need for heavier equipment tends to push no-till seeding a bit later in the spring than frost seeding. Species selection with no-till seeding is more flexible than with frost seeding, as the conditions at seeding are typically more favorable to a wider range of species. Generally, when interseeding, seeding rates are 1/2-3/4 the normal recommended rate (*Table 9, opposite page*).

Reseeding

Reseeding a pasture or hayfield is much more costly than frost seeding or interseeding, however, in some situations it may be the best option. It is best to address any underlying soil fertility and management concerns prior to making this investment. To reseed, first test soil and apply any lime in the fall prior to reseeding. Additional fertility can be added at planting as needed. Carefully consider what species are the best fit for the site and design a mixture that is both suitable and fits the farm's forage productivity and quality needs. Typically, reseeding takes place in the spring, however, farmers may also reseed pastures and hayfields in the late summer. Late summer seedings tend to experience less competition from annual weeds than in spring, though summer soil moisture is more variable and can impact establishment success. At either time, it is critical that the soil be adequately prepared prior to seeding. The seedbed should be worked so that it is fine, flat, and firm. Cultipackers can help firm the soil and can be run both before and after seeding to increase seed-to-soil contact.

Weed Management

Weeds are opportunistic species; if given a chance to establish, they do so quickly and aggressively. Therefore, the best method to manage weeds is prevention. Maintaining dense and diverse stands creates competition with weed species, making it difficult for weeds to establish. Dense stands with correctly timed harvest and grazing management on soils with adequate fertility and condition should prevent weeds from becoming problematic.

If a weed species is becoming a problem in pastures, increasing the stocking density (smaller paddocks and moving the herd more frequently) can discourage selective grazing, so livestock will eat the weeds more readily. Many weeds are nutritious, palatable, and non-toxic, so they can become part of the grazed portion of the ration. For the 100% grass-fed lactating herd, it may be best to use dry cows or heifers to do high stock density grazing in weedy pastures, while grazing the lactating cows in the higher quality pastures. Be sure to scout pastures for toxic weeds such as pokeweed or Eastern black nightshade.

It is helpful to know whether the weeds have annual, perennial, or biennial life cycles when developing a prevention or control strategy. Common pasture and hay field weeds and their associated life cycles and reproductive strategies are listed in Table 10.

Weed Species	Life Cycle	Reproductive Strategy
Bull Thistle	Biennial	Seed
Burdock	Biennial	Seed
Buttercup	Perennial	Seed, Stolons (some)
Canada Thistle	Perennial	Seed, Rhizomes
Common Milkweed	Perennial	Seed, Rhizomes
Curly Dock	Perennial	Seed
Dandelion	Perennial	Seed
Eastern Black Nightshade	Annual	Seed
Goldenrod	Perennial	Seed, Rhizomes
Knapweed	Perennial	Seed
Pokeweed	Perennial	Seed
Smooth Bedstraw	Perennial	Seed, Rhizomes
White Campion	Annual	Seed, Root Bulbs
Wild Carrot *Queen Anne's Lace)	Biennial	Seed

Table 10. Common pasture and hay field weeds, their lifecycle, and reproductive strategy.

Source: Sid Bosworth, UVM Extension

If grazing does not reduce weed pressure, another option is clipping or mowing. If grazing livestock avoid a weed, the whole plant or at least the flowers and seed stems can be clipped before the weed produces viable seed. Mowing the pasture after the cows have grazed can also reduce energy reserves and weaken larger established perennial weeds. Mow immediately following grazing to reduce damage to the most productive, fast-growing desirable pasture plants. As this timing is critical, it is important to have equipment ready to go and may make utilizing custom operators challenging. In addition, make sure not to mow too low, as this may also damage the desirable plants. Mowing may need to occur a few times throughout the season to begin to reduce weed populations. An alternative is to manually cut or dig up weedy plants. This is obviously only a reasonable option if the weeds are relatively low and localized. It is important to try to remove the plants before they set seed to diminish their populations. Fields with heavy weed pressure may be good candidates for renovation, as tillage may be more effective than attempting to control the weeds with other management practices.

Irrigation

Irrigation of pasture and other forage crops is widely used in drier climates, but there is increasing interest in irrigation in wetter climates, including the Northeast. Irrigation can reduce the number of days needed for regrowth in pastures and hayfields, especially during summer months when temperatures are high, and rainfall can be limited. If regrowth periods are shortened, more harvest or grazing cycles may be attained, which will increase overall productivity and extend the grazing season. In trials conducted in Vermont, pasture regrowth periods were reduced by 7–10 days during July and August when irrigated. Furthermore, dry conditions through September, which is typically a month of high pasture productivity in Vermont, slowed pasture regrowth sufficiently to prohibit grazing in all non-irrigated paddocks. Therefore, irrigation extended the grazing season by one grazing cycle, and irrigated pasture yields were increased by 33–75% over non-irrigated pasture yields.

There are many different design options for irrigation systems, each with varying costs, water demands and outputs, paddock design considerations, and daily management requirements. Types of systems include center pivot, pod (e.g., K-line), and traveling guns. More information about these designs and their specific considerations can be found in the resource list at the end of this chapter.

Managing Pasture Productivity and Quality

Preliminary research shows that, even in northern regions, grass-fed dairy farms are grazing their herds over 180 days each year and providing over 80% of the herd's feed from pasture during the grazing season. However, pasture productivity and quality are heavily influenced by grazing management. Shorter periods of occupation, variable recovery periods tailored to seasonal conditions, and use of smaller paddocks are critical management strategies that result in desirable, productive, nutritious, and palatable plants that grow densely and allow cows to graze more efficiently. These smaller paddocks and shorter periods of occupation will more evenly distribute animal impact and subsequent manure nutrient deposition across pastures. Managing smaller paddocks with this higher stocking density due to more frequent moves and shorter periods of occupation reduces selective grazing and weed pressure. This type of management also increases plant density, sequesters carbon, increases water infiltration, and prevents erosion.

The amount of time the herd spends in each paddock has a substantial impact not only on forage intake but also on the condition of the pasture. Ideally, cows should be left in a paddock for as long as they need to remove adequate forage without damaging the pasture. The amount of time required to do this is dependent on the number of cows, the size of the paddock, and the amount of forage available to graze. If these factors are not balanced properly, the amount of forage available in the pasture can become limited, decreasing intake and encouraging cows to overgraze. The bottom 3–4 inches of most perennial forage plants are where the plants store most of their energy; removing them can damage plants and slow regrowth. Therefore, daily monitoring of residual forage left ungrazed in a paddock is critical to making proper grazing management decisions. Ideally, at least 4" of residual forage should remain in the paddock to avoid damaging the crowns and growing points of plants and to minimize plants' recovery period.

Livestock will also reject forage around manure and urine deposits. This instinct helps them avoid areas containing parasites. The best way to manage these rejected areas is to improve the biological activity of the soil and population of insects such as dung beetles, so that manure is more rapidly incorporated into the soil. Some deworming products, such as ivermectin and doramectin are excreted unmetabolized in cattle manure and can have off-target insecticidal effects on manure-decomposing insect species on pasture. Using a higher stocking density to trample leftover plant residue will also encourage manure decomposition.

Following each grazing, pasture plants need time to rest and photosynthesize to replenish their stored energy. The amount of time a plant requires to do so is influenced by its growth rate. As growth rates slow, more time will be needed to fully recover from grazing. However, plant growth rates are not constant; they fluctuate in response to soil moisture, soil fertility, plant species, past management (such as post-grazing residual), and temperature. Therefore, the use of variable recovery periods that account for changes in plant growth rates are key to providing the highest quality pastures possible. Using variable recovery periods requires grazing systems to be flexible and farmers to closely monitor individual paddock conditions throughout the season. This requires farmers to manage some of their hay fields on a flexible basis, so fields can be grazed if need be and harvested if not. Understanding these concepts is critical in planning both stored forage and pasture needs for a grass-fed herd.

Some type of grazing plan and grazing record-keeping system will greatly improve the chances that the correct number of acres of pasture and hay are planned. A grazing plan also will make it easier to maintain a higher level of pasture intake over a longer grazing season. With a plan and record-keeping system, it is likely that the quality of pasture will be higher and more consistent.

KEY POINTS

- Quantity AND Quality: Farms that do not include grain in the ration need a larger quantity and higher quality of forage per cow. In the Northeast, grass-fed farms producing their own forages use 6 to 7 acres per cow.
- Adequate Nutritional Value + High Digestibility + Good Palatability => High Quality Forage
- Choose the right grass-legume-forb species mixture for the region, soil type, and pastures.
- Legumes help improve protein content and overall nutritional quality of a forage mixture.
- A combination of perennial and annual forages can help improve forage quality and availability.
- Dense stands maximize the amount of dry matter cows can consume in each bite of pasture.
- Following each grazing, pasture plants need time to rest and photosynthesize to replenish.
- The amount of time the herd spends in each paddock has a substantial impact on forage intake and the condition of the pasture.
- Cut when the forage is ready; don't wait for the perfect weather. The timing of the first harvest sets the season.
- Design a flexible forage program.
- Compaction of soils cause problems such as reduced microbial activity, reduced nutrient cycling, reduced forage yield and quality, and increased risk of runoff.
- Options for seeding and replanting forages include frost seeding, trample seeding, no-till seeding, and renovation.
- Good forage stands and grazing management on soils with adequate fertility and condition should prevent weeds from becoming problematic.
- Irrigation can shorten regrowth periods and increase yields of pastures and hayfields in dry conditions.

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CHAPTER THREE

Soil and Nutrient Management

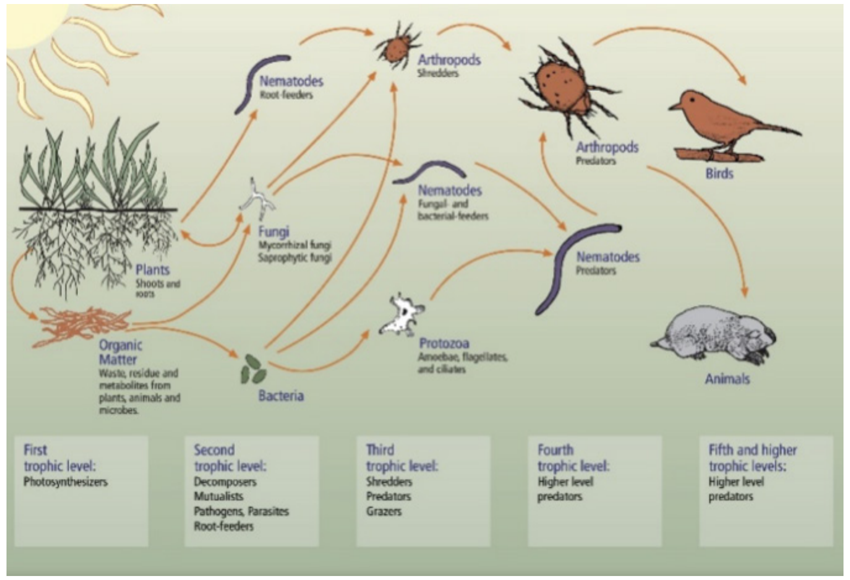
Soil Management for Crop Productivity and Quality

Maximizing soil health and fertility is critical to the success of any dairy farm. Best management practices such as good grazing systems, forage diversity, soil testing, liming, and adding fertility amendments can keep the soil healthy and forages productive and nutritious. It is important to remember that soils are complex systems composed of **physical, chemical, and biological properties**. Understanding each property and how it impacts soil function is critical in making management decisions that support crop productivity and quality.

Physical attributes of soils include texture, structure and drainage, depth, and erodibility. Soils are composed of various-sized particles of sand, silt, and clay. Sand is coarse, while clay is fine. Texture is defined by the proportions of these particles in the soil. Particles also stick together to form larger aggregates. Different-sized particles and aggregates don't fit together perfectly, leaving spaces between them through which air and water can infiltrate (Figure 8). The structure allows soil to hold and drain water, provides space for plant roots to grow, and creates a hospitable environment for soil microbes and other fauna to live.

Figure 8. Soil structure in various conditioned soil.

Source: Susan Brouillette



It may not seem like there is much life in soil, but in fact it is teeming with all kinds of life!

Farmers must address multiple aspects of each of these three properties to provide the best environment for crop production.

Figure 9. Soil biological diversity.

Source: Tugel, Lewandowski, & Happe-vonArb. 2000

The **chemical** properties of soil include the nutrients, pH, and ability for the soil to retain nutrients. These properties can be measured through traditional soil analyses and are typically involved in managing crop fertility on farms.

It may not seem like there is much life in soil, but in fact it is teeming with all kinds of life! **Biological** components make up the biological properties of soils. Soils provide homes for a diverse array of life, including earthworms, arthropods, nematodes, fungi, bacteria, and small mammals (*Figure 9, above*).

A soil's ability to balance physical, chemical, and biological properties and support productive, high-quality crops is often referred to as **soil fertility**. Farmers must address multiple aspects of each of these three properties to provide the best environment for crop production. A healthy, fertile soil should exhibit characteristics described below.

- High soil organic matter content
- High biological activity
- Good soil tilth
- Minimal to no erosion
- Proper soil pH
- Balanced nutrients

High Soil Organic Matter Content

Organic matter is composed of living, actively decomposing, and fully decomposed materials. In grass-fed dairy systems, organic matter is typically added to the soil through decaying plants and soil biological life, and manure that is deposited during grazing or otherwise spread on fields throughout the season. Microorganisms break down this organic material and incorporate it into the soil profile, where it can remain for long periods of time. Organic matter serves several purposes. First, it helps retain nutrients; organic matter particles are negatively charged and therefore attract positively charged nutrients such

as calcium, magnesium, potassium, ammonium, and sodium; this is referred to as the cation exchange capacity (CEC). Plants utilize this nutrient bank by replacing these bound nutrients with root exudates, thereby releasing them into the soil solution where they can be taken up by the plant roots. Second, organic matter helps hold water that can be accessed by plants and microorganisms as it is needed, especially in times of drought. Finally, organic matter provides habitat for the vast array of soil fauna that play a crucial role in the soil's function. Organic matter levels in perennial systems can be quite high because this material accumulates overtime and is much slower to break down. It is not uncommon to see perennial grass fields with organic matter contents above 6%, while fields that experience annual tillage may struggle to sustain 3% organic matter.

High Biological Activity

Healthy soils are very biologically active because creatures living in the soil are responsible for breaking down organic matter in to forms of nutrients that plants can utilize. For example, plants prefer to utilize nitrate (NO3) instead of ammonium (NH4) due to the extra energy required to remove hydrogen from the molecule. Ammonium can be converted to nitrite (NO2) and then nitrate through a two-step process called nitrification. Each step requires a very specialized type of nitrifying bacteria. Without sufficient populations of these bacteria, the nitrogen cycle, and ultimately plant productivity, will be compromised. Soil biological activity requires ensuring the environment is hospitable to soil microorganisms such as bacteria. Just like cows, soil microorganisms need food, air, water, and a comfortable place to live. These are provided by organic matter and access to air and water in soil pores. Therefore, soil biological activity is tightly connected to having adequate soil structure.

Good Soil Tilth

Organic matter and exudates from microorganisms help soil particles form aggregates. Between aggregates, pockets of air and water can be trapped and then utilized by microorganisms to cycle nutrients. This porous structure of soil is referred to as soil tilth. Although farmers have little influence over the texture of soil, tilth can be impacted by management. Tillage breaks compacted soil into smaller aggregates, reintroducing air and water. However, tilling wet soils can lead to compaction and poor condition. In grass-based systems in which tillage is less frequent, poor soil tilth is typically associated with compaction from haying or manure spreading equipment or from grazing animals. A general rule of thumb for identifying if soil can be tilled is to roll some soil into a ball and drop it onto the ground; if it breaks apart, the soil is dry enough to work up. Likewise, giving animals access to a pasture when the soil is too wet can be just as destructive to the soil structure as plowing it. Mechanical aeration may help alleviate compaction. Aerators are implements with blades, typically about six inches long, that penetrate into the soil and lift it slightly as they roll over the surface. This breaks up the compacted layer and introduces oxygen back into the soil, increasing water and air infiltration, stimulating microbial activity, and allowing roots to penetrate deeper into the soil profile. A keyline plow or subsoiler may also be used to aerate soils but can be more aggressive than an aerator. These implements are designed to provide aeration deep in the soil by lifting and breaking compacted layers. The metal shanks and boots come in designs that differ in the amount of soil disturbance they cause and the horsepower needed to pull them through the soil. Aeration typically alleviates compaction symptoms temporarily. Further compaction should be prevented through management and monitoring. Poor soil tilth may also be related to overgrazing damage, whereby plant roots which would otherwise help provide soil aeration and reduce compaction are diminished. Growing deep-rooted forages such as alfalfa or forage radish can penetrate compaction layers and create pore spaces to improve soil quality. Grazing management with pasture rest periods can also help prevent soil compaction and promote plant root growth.

Minimal-to-no erosion

Erosion is the act of soil being transported from one place to another by a natural force such as wind or water. Erosion is more likely to occur after soil is tilled or when soil is left bare because plant cover and root systems help to protect and stabilize the soil surface, reduce soil erosion and runoff, and increase water infiltration. When soil erodes, it takes nutrients bound to it. This can pose environmental concerns, as nutrients can be carried into a body of water where they can be detrimental. Furthermore, erosion can destabilize field slopes or banks, posing danger to animals walking over them.

> In grass-based systems, overgrazed pastures diminish the vegetative cover, leaving the soil vulnerable to erosion.

Proper pH

pH is a measure of the acidity of the soil solution. It is measured on a scale from 1 to 14.A pH of 7 is considered neutral, less than 7 is considered acidic, and greater than 7 is considered basic or alkaline. Most agricultural crops require a pH of between 6 to 7 for optimal growth because pH impacts soil nutrient availability. As shown in Figure 10, most essential nutrients are highly available within this pH range. Furthermore, many important nutrient cycling processes require soil microorganisms that thrive at similar pH levels. A soil test should be used to determine the pH, and most laboratories will provide recommendations for attaining the correct pH for the crop. Legumes prefer slightly higher pH levels than most other agricultural crops; the pH for legumes ideally should be 6.5–6.8. Of the acres surveyed in aforementioned studies, 75% were below this optimal pH for legumes. Furthermore, 46.0% of fields were below a pH of 6.0, which limits nutrient availability for any crop.

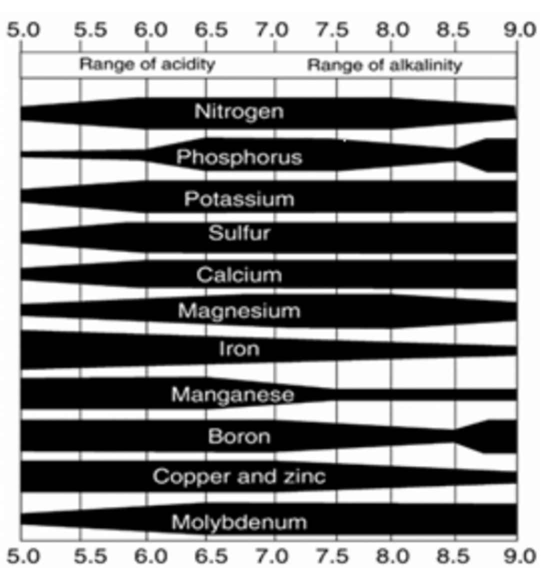


Figure 10. ph and nutrient availability.

Source: Little & McCutcheon, 2016

Balanced Nutrients

Plant nutrients are separated into two categories: macronutrients and micronutrients. Macronutrients are required by the plant in large quantities. These include nitrogen (N), phosphorus (P), and potassium (K). Micronutrients are required by the plant in small quantities. These include boron (B), calcium (Ca), chlorine (Cl), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn). Although required in small quantities, trace minerals are integral in many growth and maintenance functions for plants, just as micronutrients are important to livestock. Soil testing helps identify current nutrient levels in soil. Soils deficient in any of these nutrients will translate into poor crop yields and quality. Therefore, correcting nutrient deficiencies, especially prior to seeding, is critical to maximizing crop productivity and quality. Fertility can be added through purchased fertilizers, importing manures, or growing leguminous crops. Farmers who rely on legumes to supply N should make sure soil pH and micronutrient levels, especially B, will support legume growth. Proper balance of macronutrients and micronutrients is dependent on previously mentioned factors like proper pH, appropriate soil structure, and good biological activity. Varied fertility amendments such as manure, composts, lime, rock dusts, and other mineral fertilizer sources can both help improve crop nutrition and support soil biology and physical properties. More information about soil testing and developing nutrient recommendations is found in the resource list at the end of this chapter.

Case Study: Soil Fertility on Organic Dairy Farms in Vermont

With a long history of dairy farming in the state, many Vermont farms observe excessive soil nutrient levels that if not properly managed can pose a threat to the environment. Through courses offered by Dr. Heather Darby at the University of Vermont Extension, farmers have learned basic soil, crop, and nutrient management strategies they can implement on their farm to grow high yielding crops while protecting surrounding natural resources. She has seen an increasing number of grass-based organic and other dairy farms participate in related courses. Instead of seeing excessive fertility levels, many farms have seen nutrient-deficient fields that require substantial fertility additions to meet crop demands. To investigate this finding, organic dairy farmers participating in these courses in 2015 shared their soil fertility data with UVM Extension. Of the 3,000 acres included, 78% and 91% had soil test levels below the optimal level for crop growth for phosphorus (P) and potassium (K), respectively. Less than 5% fell into the "excessive" category for either nutrient. Based on their nutrient application records, farms were not meeting the nitrogen (N) demand of the crop on 92% of their collective acreage. Several factors seem to be influencing this. It may not seem like it, but grass requires a lot of N. A stand of perennial cool-season grass (such as orchardgrass) producing 3–4 tons of dry matter per acre across the season requires **150 lbs. of N per acre**. Conversely, a mixed stand of grass and N-fixing legumes producing similar yields requires only 40 lbs. of N per acre. The majority, 57.9%, of the acres included stands with <20% legumes. With the increased land often needed to meet organic grazing standards, manure resources on organic farms are spread across more acres than on a comparably sized conventional farm. Therefore, meeting the N needs of an all-grass stand on an organic farm can be very challenging without importing additional nutrients.

75% of fields below optimal pH > 58% have <20% legume > 92% of fields not meeting crop N need

Grass-fed Dairy and Soil Management

While soil principles apply to grass-fed farms, farms that transition to grass-fed must consider additional specific factors. As previously mentioned, on grass-fed farms there is no grain, and nearly 100% of the diet must come from forages. To achieve the level of nutrition required to feed an all-forage diet to the herd, the soil must be able to provide adequate nutrition to forages.

Since cows only eat forage, the amount of forage required to feed the herd will increase. Likewise, the number of acres of land to be able to grow the increased amount of forage will also increase. Maintaining yields and quality on an expanded land base needs to be recognized as an investment and cost to transitioning to grass-fed dairy. To minimize the number of acres required, farmers should prioritize maximizing yields and digestible fiber per acre.

Generally, most organic farms fertilize with their own manure. Some farms also import additional nutrients to maintain fertility. If transitioning to grass-fed production, it is likely that the amount of manure and the quality of the manure will change during the transition. Manure production of an animal is directly related to milk production and dry matter intake. Higher milk production stems from higher dry matter intake of animal and results in increased manure production. A farm that once produced 60 pounds of milk per animal per day may decline to 30 lbs. of milk per animal per day in grass-fed production and thus will produce 26 pounds less manure per animal per day (Figure 11).

In addition, nutrient concentrations in manure will change. The less grain fed, the lower the nutrient concentration in the manure will be. As seen in Figure 12, dairy animals that are fed conventional diets, which often include higher levels of grain, generally have higher nutrient concentrations in their manure. As farms transition to organic, less grain is generally fed to animals due to cost, animal health, and changing milk production goals. In grass-fed systems, with no grain at all, nutrient concentrations in manure can drop by 50%. Although grain is a costly input, it helps provide valuable dry matter, nutrients, energy, and protein to cows, supplementing the forage available on the farm. Nutrients not utilized by the animal make their way into the manure and back on to the fields. This nutrient input no longer exists on a grass-fed dairy. Purchasing forage is an option and could serve as a valuable input to the farm. Otherwise, it is likely that purchasing external fertility sources will be necessary to maintain the productivity and quality of the forages.

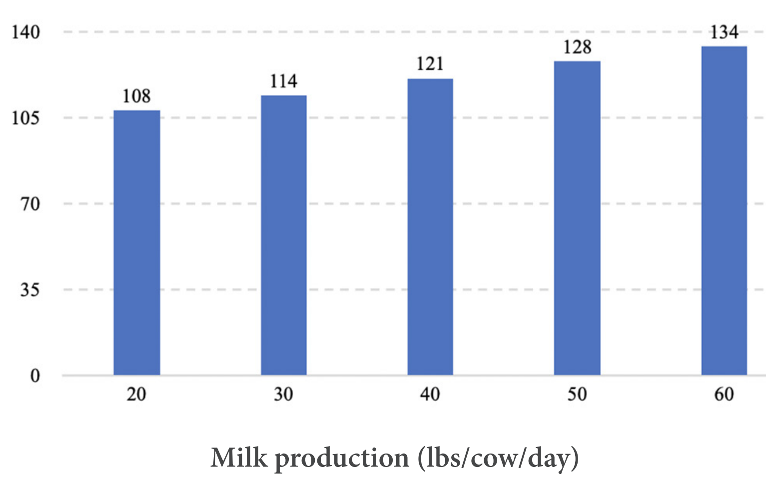


Figure 11. Manure production (pounds per animal per day) as influenced by the level of milk production (pounds per animal per day).

Source: Heather Darby, UVM Extension

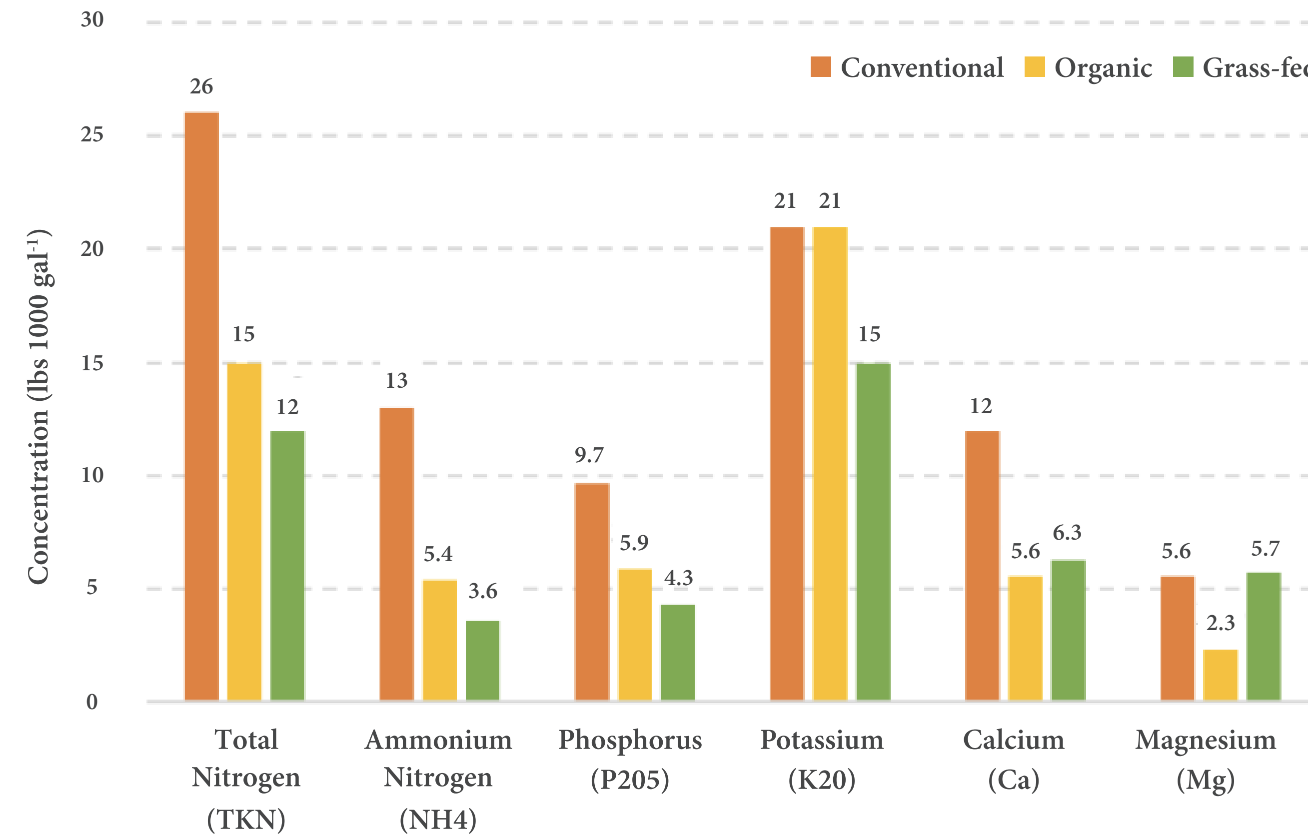


Figure 12. Nutrient concentration of manure from different farming systems feeding different amounts of grain.

Source: Heather Darby, UVM Extension

Whole Farm Nutrient Balancing: Unique Challenges for the Grass-fed Dairy

Although balancing nutrients in soil is important, it cannot be considered in isolation from the nutrients and composition of other components of the farm. This is called Whole Farm Nutrient Balancing. Whole farm nutrient balancing is essentially like balancing a checkbook of nutrients coming onto and leaving the farm. Farms import (or deposit) nutrients through purchased feed, bedding, fertilizers and other soil amendments, minerals, and imported manures. Farms export (withdraw) nutrients from the farm through the sale of animals, milk/meat, crops, and other products. Issues can arise when there is a severe imbalance between imports and exports, especially over long periods of time. If more nutrients come on to the farm than leave, nutrient levels in soils will continue to rise and ultimately may pose risks to the environment. On the other hand, if more nutrients leave the farm than are imported, soil fertility will decline and ultimately crop, and animal productivity will suffer.

On most dairy farms, large quantities of nutrients (like phosphorus and trace minerals) are brought onto the farm in the form of grain. The grain is fed to cows, adding nutrients through the farms' manure supply, which then is spread on the land used to produce forages. Eliminating the import of grain nutrients in a grass-fed system without a clear plan to maintain soil fertility leads to depleted soil nutrient levels and, consequently, poor forage productivity and quality. In addition, due to increased land needs to support a grass-fed herd, grass-fed farms may have less manure to spread per acre, further depleting soil nutrient reserves if additional fertility is not imported. This is often exacerbated by the fact that available organically approved fertilizer options are limited and often considerably more expensive than conventional options. Understanding the implications and costs of nutrient imbalances is crucial to long-term success of farms. Since forage production and quality can fluctuate significantly, poor nutrition poses numerous risks to the herd and farm economics. Therefore, it is critical to identify significant nutrient deficits and address them before they negatively impact the farm. To maintain productivity of animals and land, changes to nutrient imports and exports must be evaluated as a farm considers transition to grass-fed and then monitored over time.

Let's dig into this a bit more with three examples evaluating the whole farm nutrient balance: first of an organic farm, second of a grass-fed farm with purchased fertility, and third of a grass-fed farm with no purchased fertility. In the first example, an organic dairy is feeding grain and buying forage. Exports from this farm are primarily from milk but also some from cull cows and compost sales. As seen in Table 11, the farm is operating in a slight nutrient excess, with nitrogen (N), phosphorus (P), and potassium (K) accumulating each year.

Organic Farm Whole Farm Nutrient Balance	N	P	K
Imported (tons) Grain, Baleage, bedding Minerals	5.64	1.00	3.57
Exported (tons) Milk, Meat, Compost	2.66	0.45	0.71
Balance (tons)	2.98	0.55	2.86
lbs./hundredweight (CWT)	0.87	0.16	0.84
lbs./acre	56.8	10.5	54.5

Table 11. Example of a whole farm nutrient balance in tons of nitrogen, phosphorous, and potassium on an organic dairy farm (48 cows, 20 replacements, 105 acres) that feeds grain.

Source: Heather Darby, UVM Extension

In comparison to a grass-fed dairy, more than double the acreage is required to feed a similar number of cows. Since there are no grain imports in grass-fed production, fertility is brought on to the farm in the form of poultry manure. As shown in this example, the quantity of imported nutrients is low and nearly all from the poultry manure. The level of exported nutrients exceeds the nutrients coming on to the farm (Table 12). In the third example, the same grass-fed farm does not import poultry manure to fertilize, and consequently all nutrients are at a deficit (Table 13).

When evaluating whole farm nutrient balances, these types of imbalances can be helpful at times (for example, to draw down high soil P), but long-term draw down of nutrients is harmful to production. Evaluation of whole farm nutrient balances is critical to monitor and balance nutrient flows on the farm.

How to avoid these pitfalls? Farmers should start by evaluating the soil nutrient levels through conducting basic soil samples and calculating the whole farm nutrient balance to develop a baseline. The "Whole Farm Nutrient Mass Balance Calculator" developed by Cornell University is an easy-to-use tool intended to help identify opportunities for improvements on dairy farms. Farmers should monitor yields and fertilize (starting with manure) to achieve yield goals. Fertility needs of forages can be quite substantial, depending on the desired yield. In stands that consist primarily of grass, every ton of dry matter will require 50 lbs. of N, 17 lbs. of P, and 50 lbs. of K. And the more dry matter harvested per acre, the higher the nutrient needs of the crop.

Nutrients and amendments should be applied to meet a realistic yield goal. Manure is a complete fertilizer and contains all 13 nutrients that the plants require. However, to provide this level of nutrients, a substantial amount of manure must be applied and may limit the number of acres that can be spread. Further, with lower quantity and quality of manure, it is pertinent to think about other nearby sources of fertility. Accessing manure from other farms might be a cost-effective option to maintain P, K, and other nutrients. To meet N demands of grasses, legumes should be incorporated into the cropping system. As seen in Table 14, mixed stands can produce higher yields of forage and replace the need for supplemental N additions. Practices such as frost seeding or using a no-till drill to add seed on a regular basis can help maintain legume levels. Although there are many factors and practices that influence forage quality and quantity, soil fertility and health are primary drivers that will require monitoring and investment to be successful with grass-fed dairy.

Grass-fed Farm Whole Farm Nutrient Balance	N	P	K
Imported Fertility Poultry manure, minerals	0.08	2.06	0.8
Exported (tons) Milk, Cull Cows	1.83	0.34	0.53
Balance (tons)	-1.03	1.72	0.27
lbs./CWT	-0.32	0.53	0.08
lbs./acre	-8.62	14.32	2.27

Table 12. Example of a whole farm nutrient balance in tons of nitrogen, phosphorus, and potassium on a grass-fed dairy farm (48 cows, 40 replacements, 240 acres) that imparts fertility.

Source: Heather Darby, UVM Extension

Nitrogen Treatment	DM Yield Tons/acre
N Fertilizer	1.25
Grass-Legume Mix	1.28
Grass Alone	0.607

Table 13. Grass yield from one harvest when grass is grown with N fertilizer, with legume, and alone.

Source: Heather Darby, UVM Extension

Grass-fed Farm Whole Farm Nutrient Balance	N	P	K
Imported (tons) Minerals	0	0.51	0.05
Exported (tons) Milk, Cull Cows	1.83	0.34	0.53
Balance (tons)	-1.83	0.17	-0.48
lbs./CWT	-0.57	0.05	-0.15
lbs./acre	-15.3	1.41	-3.98

Table 14. Whole farm nutrient balance of a grass-fed dairy farm (48 cows, 40 replacements, 240 acres) with no imported fertility.

Source: Heather Darby, UVM Extension

Example: Nutrient Management to Meet Forage Needs

In the chapter on forage management, an example looked at a farm milking 60 cows on 170 total acres, including pasture that yielded 1.75 tons of DM/acre and hay fields that yielded 2.5 tons/acre. This would produce a total of 373 tons of DM/year from hay and pasture. The forage intake needs for the whole herd, including youngstock, was 550 tons of DM/year, so the farm was short 177 tons of DM per year.

If the farm could improve soil fertility and soil health to increase yields in the pasture to 2 tons of DM/acre and up to 3 tons/acre in the hay fields, then the farm would only be short 110 tons of DM per year. Though the farm would need to purchase more fertility inputs, it would avoid the expense of buying 67 tons of DM forage, the equivalent of about 268 round bales, each year.

Raising yields by 0.5 ton per acre is achievable and, on a basic level, could be accomplished through evaluating soil fertility needs and likely adding legumes to boost yields. The cost of nutrients to gain this level of yield would include an additional 25 lbs. N, 10 lbs. P, and 25 lbs. K.

The farm will need to purchase feed to meet remaining nutrients, but splitting expenses between purchased feed and soil management may prove to be a good investment. The purchased forage will allow nutrients to be brought onto the farm and further build fertility while also providing nutrition to the cattle.

KEY POINTS

- **Soil pH** is a measure of the acidity or alkalinity of the soil: neutral = 7, acidic soil < 7; basic or alkaline > 7. Most agricultural crops experience optimal growth at a pH of 6 to 7.
- To **minimize erosion**, ensure fields have sufficient vegetative cover and avoid over grazing.
- **Soil tests** identify current nutrient levels in the soil, thus indicating deficiencies requiring soil amendments and/or management changes.
- A healthy, fertile soil should exhibit high soil organic matter content, high biological activity, good soil tilth, minimal erosion, proper pH, and balanced nutrients.
- Tracking all nutrients coming onto and leaving the farm through a tool called **whole-farm nutrient balancing** can be used to ensure adequate soil fertility.
- In the transition from conventional to grass-fed production, the elimination of grain nutrient imports and the increase in land needs per cow can lead to soil nutrient depletion and poor forage productivity/quality if not intentionally managed.

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CHAPTER FOUR

Herd Health, Nutrition, and Management

Dairy Cattle Physiology and Nutrition

The goal of herd management is to meet the nutritional and behavioral needs of dairy cows to optimize health and well-being so the animals can express optimal growth and productivity. Food, water, and comfort are the basic needs of dairy cows. With 100% grass-fed dairy, the most limiting basic need is likely be nutrition, mainly meeting energy demands. Without adequate quantity and quality nutrition, cows will be unable to keep up with the physical demands of lactation and will decline in production and health. Without a nutritionist from a grain company helping to balance rations as forage quality changes over the year, it is helpful to be well-informed on nutrition or hire an independent nutritionist.

To meet feed requirements, farmers must know:

1) what nutrients cows need,

2) the quantity needed, and

3) the nutritive content of available feedstuffs.

This information will help farmers provide cows a balanced diet that supports high milk yield and quality while supporting cow health and longevity. More information on forage quality is found in chapter 2.

Digestion Physiology

Cows are ruminants, meaning they have complex four-chambered stomachs. This complex system allows cows to digest plant material that is indigestible to non-ruminants. The major component of this system is the rumen. It is the largest of the four compartments, holding 25+ gallons of material. The rumen is full of microorganisms that are responsible for breaking down the plant material cows consume into more useable compounds through a fermentation process. Carbohydrates in feeds are fermented by the microorganisms to produce volatile fatty acids (VFA), which are absorbed and utilized by the cow as energy. These microorganisms then pass to the lower abomasum and small intestine, where they are digested and absorbed as the primary source of protein. To determine the amount of pasture and stored feed needed, the farmer must:

1. Determine how much feed from pastures to include in the ration during the growing season.
2. Determine type, size, and total number of cows and total replacement animals from birth to calving.
3. Determine total number of acres available to the whole herd.
4. Determine realistic yields.
5. Account for realistic levels of harvest, grazing, or storage losses.

More information on monitoring DMI and the factors impacting it can be found in Chapter 4.

Nutrition Basics

Energy

Energy is the most critical component for animal livelihood, maintenance, growth, and productivity. Energy is required on a much larger scale than protein. In fact, requirements of protein and other nutrients are relative to energy status of the animal. Energy is required to perform routine bodily functions and for milk production. Just as in human diets, cow energy requirements change based on size, age, and activity. Meeting energy demands for a 100% grass-fed herd is essential and can be difficult if forage quality is not adequate.

Carbohydrates (CHO) are the primary source of energy for rumen microbes and ruminant animals, typically accounting for 60–70% of the diet. CHO are classified as either structural or non-structural, relative to their function in the plant. The structural CHO are the fiber portion, while the non-structural are the non-fibrous carbohydrate (NFC) fractions.

The fibrous portion of feeds and forages is composed of cellulose, hemi-cellulose, and portions of soluble fiber, including a large group of highly digestible pectin-like compounds (which are very high in grasses). The most common measure of fiber is neutral detergent fiber (NDF), which is comprised primarily of hemi-cellulose and cellulose and has some proteins and ash. More information on forage fiber fractions and forage analyses can be found in chapter 2.

NFC carbohydrates include organic acids (OA), sugars, starch, and soluble fiber. Estimates of NFC are rather crude assessments of the more highly digestible and more energy-dense portion of a feed. They are not analyzed in the laboratory. Rather, NFC is roughly estimated using the equation: NFC = 100 – (NDF + CP + Fat + Ash). Improved analyses of OA, sugars and starches allows farmers to forgo the use of NFC in nutrition and be more precise in energy estimations of feeds and forages.

These more precise fractionations of CHO allow for not only more accurate estimation of proportions of each in various feeds, but also improved estimation of their digestibility in the rumen, the lower gut (small intestine), and hind gut (large intestine). This provides a better estimation of energy contribution as well as microbial growth and subsequent microbial protein supply to the animal.

For many years total digestible nutrient (TDN), a summation of digestible protein, fiber, fat, and non-nitrogen containing extracts, was used to assess energy value of feeds. The Net Energy System was developed to estimate energy demands for different goals. This system represents the amount of energy required by an animal for growth, maintenance, lactation, and other functions. These are expressed as NEG, NEM, and NEL respectively. Net energy of lactation (NEL) is the energy required by a cow for milk production. This system is based on ADF and lignin to estimate the energetic value of fiber. Lignin, a plant phenolic polymer much like plastic, has been analyzed and used to predict the indigestible portion of fiber; so, the more lignin the less digestible the fiber. However, improved analyses have shown that lignin alone does not account for all variations in fiber digestion. Other factors such as crystallinity of the cellulose, yeasts, and molds also can negatively affect fiber digestibility.

Current analytical methods to determine NDF digestibility (NDFD) involve use of rumen fluid to digest fiber for certain lengths of time. There is considerable debate over which time points/lengths of fermentation most accurately estimate true ruminal digestion. The Cornell system relies on 30, 120, and 240 hours of fermentation, while other systems focus on 24 and 48 hours of fermentation. Recently, a 12-hour time point has been introduced for highly digestible forages such as pasture grasses, lush conventionally raised forage, and low lignin BMR (brown mid-rib) varieties. The NDF digestibility of non-forage feeds relies on 12, 72, and 120 hours of fermentation in the Cornell system. The use of NDF digestibility results in more robust digestion profiles that vastly improve the estimation of metabolizable

energy (ME) from forages and the estimation of undigested fiber filling the rumen. Rumen fill with low digestibility fiber negatively impacts dry matter intake and thus limits performance. Balancing the level of degradable fiber for energy and undegraded fiber for proper rumination and rumen dynamics is the art and science of achieving both optimal production and animal health.

While our analytical precision has improved, the main principles governing daily feeding of grass-fed dairy cows remain: CHO are critical sources of energy and are composed of both non-structural (sugars, organic acids, and starches) and structural (fiber) components. Maximizing both the concentration and digestibility of these fractions are critical to maximizing metabolizable energy in the ration. Balancing dairy rations, even when no grain is fed, can be challenging, as it requires accurate information on dry matter intake, forage quality, and the animal's nutrient requirements. Working with an experienced nutritionist is recommended, as nutritionists have access to modeling tools to help calculate nutrient requirements and supplies from stored feed and pasture.

Protein

Proteins are made up of amino acids (AA). Amino acids are unique because they contain the essential element nitrogen (N) and, as key components of enzymes and hormones, amino acids perform a variety of specific functions in animals. Of the 22 different AA, 9 are essential in mammals. Analyses for protein content of feeds has long relied on analyzing for total N and calculating a protein value using a conversion factor based on AA composition of proteins in the material. For feeds and forages, total N x 6.25 results in a crude protein (CP) value. However, many feeds also contain N that is not associated with AA, including in urea, ammonia, and nitrate. These "free" N sources can artificially raise the CP value of a feed through the above calculations, but these free N are not part of amino acids and therefore are not proteins. Hence the term "crude" protein differentiates from true protein (TP) which is the sum of amino acids. Nitrogen not associated with AA is referred to as non-protein N (NPN).

Fortunately, the rumen microorganisms can ferment fiber and other CHO in conjunction with proteins and NPN to create their own AA and proteins. These microbial proteins are eventually digested in the lower gut and provide the bulk of AA utilized by the animal. The sum of feed and microbial proteins/AA digested, absorbed, and utilized by the animal is referred to as metabolizable protein (MP).

Feed proteins are divided into various fractions depending on type and rate of rumen degradation:

- CP approximates the total amount of protein contained in a feed based on the nitrogen content. Proteins vary in their chemical and physical properties, which affects their utilization and nutritional value. Estimating MP is based on the degree of protein solubility and degradability.
- Soluble protein (SP) is the protein fraction that is soluble in the rumen fluid digesta. These "proteins" are primarily NPN and some TP amino acids.
- Degradable protein, or rumen degradable protein (RDP), is the protein that can be rapidly broken down by rumen microorganisms. The amount of RDP and rate of degradation in the rumen depends on its chemistry and how long it stays in the rumen, which varies with intake and digestibility of the total ration.
- Rumen undegraded protein (RUP) is the fraction of protein that is very slowly degraded in the rumen or likely to pass through undegraded but is digestible in the lower gut/small intestines of the animal. In the past, the term bypass protein has been used to reflect proteins that escape the rumen undegraded. However, this concept is outdated, as it infers a unique and independent fraction of protein. The rumen degradability and hence undegraded fractions of proteins and CHO depend on the

status of the animal and length of time feeds remain in the rumen subject to microbial degradation.

- Indigestible protein is the fraction which passes through the animal's entire digestive tract undigested. Feeds that experience extreme heat-treatment, such as soybeans that are over roasted, or byproducts, such as distillers' grains, can have proteins that become caramelized and damaged. They typically are darker in color and have a tobacco-like smell.
- Microbial CP is the protein generated by the rumen microorganisms resulting from the degradation of fiber, starch, and sugars. Starch fermentation yields slightly more microbial growth than fiber and sugar. Therefore, in all grass rations, maximizing intake and the digestibility of the fiber will optimize microbial growth and supply of microbial protein for the cow.

Fats

Fat is a very general term used to describe feeds that contain a large proportion of long-chain fatty acids (FA). FA are chains of carbon atoms, generally in straight or kinked lines. Fats may be in the form of oils or solids at room temperature. Chemically speaking, FA that have a full complement of hydrogen atoms are called saturated fats and tend to be in solid form at room temperature. Unsaturated FA do not have a full complement of hydrogen atoms and tend to be in liquid form at room temperature. The degree of saturation varies among unsaturated FA from a single degree (mono-unsaturation) to polyunsaturation. Vegetable oils are high in polyunsaturated FA (PUFA), while lards and butter are higher in saturated FA. The fats in dairy products tend to be high in saturated FA and mono-unsaturated FA as opposed to PUFA.

Forages may not have much fat, but the FA they contain tend to be PUFA, some of which are essential in human nutrition. Fiber digestion can be inhibited by high levels of PUFA, since they may be toxic to some rumen microbes. However, rumen microorganisms are very active in altering the chemistry of FA and may convert one FA to another. Converting PUFA to saturated FA occurs through a process called biohydrogenation and depends on a number of factors, including the amount of available FA and rumen pH. The process involves a number of steps and, if incomplete, can result in the production of a specific FA, CLA 18:1t. This FA is a potent inhibitor of milk fat production in the cow and likely the primary cause of reduced milkfat of grazing animals.

Standard analyses of "fat" in feeds is done through the ether extract (EE) procedure. This procedure yields true fats as well as other ether-soluble compounds including pigments (chlorophylls) and tannins. The resultant value is expressed as either EE or Crude Fat. The amount of true FA is then estimated from these values for a given feed.

Minerals

Minerals are inorganic, non-carbon containing elements required for life functions including maintenance, growth, reproduction, and lactation. Minerals are classified as either macro- or micro- based on the scale to which they are required. Macro minerals include calcium (Ca), phosphorous (P), sodium (Na), chloride (Cl), potassium (K), magnesium (Mg) and sulfur (S). Macro minerals play roles in structure, bone, and tissue, body fluids, acid-base balance, osmotic pressure, and the electrical functioning of the nervous system. Micro minerals may also be referred to as trace minerals since they are required in such trace amounts. Micro minerals include cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), zinc (Z), chromium (Cr), and fluorine (F). Micro minerals are critical parts of body fluids, enzymes, and hormones. In addition to animals' requirements, the rumen microflora also have strict requirements for minerals, especially S, Cu, and Mg.

Animals' ability to absorb any given mineral is quite variable and depends on the mineral and the source, such as forage, grains, "rock," or "processed "rock." Based on the source of mineral, there are absorption coefficients (AC) for each mineral. For instance, the AC of Ca in forages is estimated to be 0.30. This means that only 30% of the Ca in grass is actually absorbed by the animal. The AC for Ca in grains is 0.60, meaning there is a 60% rate of absorption of this source of Ca. The AC of Mg is quite low, only 0.16 for all feed types. The AC of Na, Cl, K is quite high, 0.90 across all feed types. It is also important to note that there are many interactions between minerals in the rumen that can interfere with absorption and decrease the AC even further. For example, high levels of S and Fe can reduce the absorption of Cu and Se and thus possibly result in deficiencies.

While grain-fed dairy cows meet most of their mineral requirements from grain fortified with minerals, grass-fed animals require mineral supplementation. Balancing for proper mineral nutrition in grass-fed rations can be difficult, and when done incorrectly is likely to result in some mineral deficiencies. A research trial of cows producing 47 lbs. milk, consuming 38 lbs. of dry matter (DM) as ryegrass pasture only and no grain, shows mineral levels provided in the diet, the animal requirements, the net surplus/deficiency, and percent of requirements of absorbed mineral (Table 15). In the research trial, only 57% of the animals' requirement for absorbed Ca is being met. Cu and Zn are the next most limiting, while Na and S are barely meeting requirements. Cl is in excess, at >300% of the requirement. Note the grams of absorbed mineral relative to supply result in the +/- balance.

Trial	Diet	Absorbed			
	Concentration	Supplied	Requirements	Balance	% Reg
Ca	0.55 % DM	28.52 g	50.07 g	-21.55 g	57.0 %
P	0.42 % DM	46.16 g	38.56 g	+7.60 g	119.7 %
Mg	0.21 % DM	5.83 g	4.90 g	+0.92 g	118.9 %
K	2.84 % DM	439.35 g	157.72 g	+281.62 g	278.6 %
Na	0.22 % DM	34.38 g	34.32 g	+0.06 g	100.2 %
Cl	0.72 % DM	111.51 g	36.83 g	+74.68 g	302.8 %
S	0.22 % DM	37.72 g	34.40 g	+3.32 g	109.6 %
Mn	75.70 ppm	13.02 mg	1.86 mg	+11.16 mg	698.6 %
Cu	9.88 ppm	6.80 mg	7.77 mg	-0.97 mg	87.5 %
Fe	363.37 ppm	625.00 mg	27.96 mg	+597.04 mg	2235.7 %
Zn	29.43 ppm	75.90 mg	114.06 mg	-38.16 mg	66.5 %
I			8.16 mg	-8.16 mg	0 %
Co			1.89 mg	-1.89 mg	0 %
Se	0.01 ppm	0.12 mg	5.16 mg	-5.04 mg	2.3 %
Cr			6.88 mg	-6.88 mg	0 %

Table 15. Example mineral supplementation rotation.

Source: Kurt Cotanch, Barn Swallow Consulting

Since mineral nutrition is likely a weakness in grass-fed rations, it is important to have the best mineral analyses of forages. The most accurate mineral content analysis for feed and forage uses "wet chemistry" methods (see Assessing Forage Quality in chapter 2). It is also important to consider other field-based factors that can impact mineral content of the feed. Mineral availability and uptake into forage plants can vary by species, the mixture of legume and grass, soil type and parent material, soil nutrient deficiencies/excesses, season, manure and fertilizer application, etc. For example, in the spring, cool season grasses in the northeastern U.S. tend to accumulate K if it is available in the soil to the point that it can be too much K for dry cows. In addition, diverse pastures can contain a wide range of forage plants and weedy species that all differ in their mineral contents. Many soils in the northeastern U.S. are low in Se and I, and therefore the forages tend to also be low in these trace minerals. Conversely, some western soils have high Se levels, and toxicity can be a problem in those areas. Since these factors vary from farm to farm, it is important to develop a plan that will address farms' specific needs. Working with a nutritionist or veterinarian and testing forages will allow farmers to design the ideal mineral supplementation program.

In developing a mineral supplementation program, consider how cows will be fed the minerals. There are multiple formulations of minerals available, including lick blocks and loose mixes. Grass-fed certification does not allow any grain or grain by-products, even in small amounts, in the mineral mix, so mineral formulations should be carefully reviewed and approved by the certifier. Lick blocks are slow for cows to ingest in necessary quantities, so loose mixes are more commonly used. Loose mixes allow cows to quickly ingest more minerals per "bite." Some essential minerals also have low palatability and can be avoided by cows. To combat this, some farms mix kelp or a trace amount of molasses into the loose mineral mix to increase palatability. Others top dress or mix loose mixes into forage prior to feeding the herd.

During the grazing season, when the cows spend little time in the barn or may not be eating much supplemental feed, it can be particularly challenging to maintain mineral intake. Mobile mineral feeders, which are available for sale or can be built, can easily be towed out into a pasture to provide cows easy access to minerals. They typically have rubber covers to protect the minerals from moisture and contamination, but cows can easily lift the rubber covers with their muzzles (Figure 13). **Free choice, cafeteria-style mineral feeders should not be relied upon to meet all the cows' mineral requirements.** More information on mineral feeders and suppliers can be found at the end of this chapter.

Mineral deficiencies

There are several common mineral imbalances or deficiencies that affect all dairy cows but may be more prevalent in cows with all-grass rations. Mineral deficiencies appear to be most common on farms that have recently transitioned to all-forage rations and may include both acute deficiencies and ongoing sub-acute deficiencies, which can be harder to diagnose and address. In hindsight, many farmers realize that mineral deficiencies started early in the transition to 100% grass-fed. As the amount of grain was slowly reduced, the mineral concentration of the grain was not adjusted to compensate for lower intake. For example, a grain formulated to be fed at 18 lbs. per cow per day won't provide enough minerals when it is fed at only 5 lbs. per cow per day. So, unless additional minerals are fed to compensate, the herd mineral intake becomes lower than needed. By the time the herd is fed just forages, in some cases there are obvious deficiency symptoms.

- Common symptoms of mineral deficiency include:
- Milk fever, due to low blood Ca concentration
- Grass tetany, due to low blood Mg concentration
- Poor conception and reproduction

- Weak calves
- Retained placentas
- Rough hair coats

Evaluating for mineral deficiencies in animals is rather difficult and often inconclusive without visible signs of acute deficiencies. However, many of these conditions can be avoided by proactive prevention strategies. It is best to work with a nutritionist or veterinarian on a mineral feeding program to prevent deficiencies. If a mineral deficiency is suspected as the cause of herd health or productivity problems, diagnostic work by a veterinarian may be needed. See the end of this chapter for additional resources.

Vitamins

Vitamins are organic molecules required in very small quantities. They are critical for many metabolic functions, the immune system, and gene regulation. Vitamins are classified as either fat- or water-soluble. Fat-soluble vitamins include A, D, E, and K. Water-soluble vitamins include the B vitamins and vitamin C.

Adequate levels of vitamins A and E need to be provided in the ration. Vitamin A is a family of compounds including beta-carotene and retinols required for proper vision. Lush grasses contain significant amounts of vitamin A; however, vitamin A deteriorates quickly and levels in mature grasses and dry hays are much less than in lush forage. Winter feeding of vitamin A will be required. Vitamin E (tocopherol), as with vitamin A, is higher in fresh forages but will diminish greatly after harvest and with plant maturity, so winter feeding of vitamin E is also recommended.

Vitamin D is generated by sunlight/UV exposure. Vitamin K and B vitamins are synthesized by microbes in the rumen and small intestine. Vitamin C is synthesized by the liver and kidney. These vitamins are typically synthesized at sufficient levels and are not typically supplemented.

Water

Although it may not be thought of as a traditional nutrient, water is perhaps the most essential nutrient for dairy cattle. Total water requirements are driven by a number of factors including age, body weight, dry matter content of the diet, climate/temperature, milk production, and Na intake. The total water requirement is met through drinking water and water contained within consumed feeds.

Lactating cows can consume about 3 lbs. of water per lb. of milk produced. Quality and accessibility of water is very important. Periodic testing of water for solids, salinity, sulfates, nitrates, Fe, Mn, and standard water quality profile is highly recommended. If people would not drink the water because it is dirty, it may not be advisable for the herd either. Large tubs of stagnant water can limit consumption. Take into consideration the water tub depth, rates of consumption, and refill capacity of the tub. Minimize walking distance to <50 feet to water. When grazing, this means having a water tub in each paddock or within a short distance of the paddock entry. Have easy access to water after milking, as up to 60% of water consumption occurs shortly after milking.

Ration Formulation and Dry Matter Intake

To appropriately combine available forages to meet the needs of various animal groups on the farm, forages must be segregated based on quality. Rations can then match complimentary pastures, dry hay, and haylage according to animal requirements and availability.

In northern regions, pasture forages act like a forage in the rumen at the beginning of the season and act like a concentrate in the rumen at the end of the growing season. Fiber accumulation in spring and early summer is completely different than in late summer and fall. Because sunlight is the main energy source of plants, plants mature and accumulate fiber at a much faster rate early in the season than later in the season. Longer days also increase the sugar content in plants, which can sometimes lead to ruminal acidosis, particularly when the rumen is not quite ready to deal with heavy acid production at the beginning of the grazing season. Sugars are important in the rumen because they provide a rapid source of energy to maintain and optimize microbial populations in the rumen. When microbes leave the rumen, they become the main cows' main protein source.

For haylages, farmers need to identify the excellent fermented haylage and the haylage that did not ferment as planned ("sinking silage"). For dry hay, farmers need to identify the hay that only contains leaves and the dry hay that contains stems and leaves. Here are some suggestions on how to match different forages together:

1. When pasture is in the diet, try to avoid adding haylage with compromised fermentation.
2. Leafy hay (no stem) should be prioritized for young calves up to 4 months of age.
3. Pasture should always be complemented with excellent haylage or dry hay to optimize the structure of the rumen mat.
4. The best forages on the farm, regardless of the source (pasture, haylage, dry hay), should be fed to early lactation cows first. The next group to access the best forages should be calves 4-8 months.
5. Given this prioritization, the gymnastics of matching the remaining forages starts here. This is where all the compromises begin.

The last step of ration formulation is to estimate as realistically as possible total dry matter intake (DMI). This is particularly challenging when grazing. The closer to reality this estimate is, the better the herd will perform in production, components, and reproduction. One factor that can make this estimate less accurate is sorting. Cows are selective grazers. When plants mature, cows strip plants to only eat the leaves or will favor less mature species. The same sorting activity can happen with stored forages. If sorting occurs, the DMI of fiber will differ from the estimate, and this compromises the ruminal mat structure.

A major factor in whether stored forages are sorted or not is particle size. While forage particle size is often thought to only be a concern in total mixed ration (TMR) systems, particle size is critical in all dairy systems as it influences rumen dynamics, fiber digestion, and microbial yields, and thus particle size also affects VFA production, ruminal and animal health, DMI, and quality of fermentation in ensiled forages.

The concept of physically effective Neutral Detergent Fiber (peNDF) was introduced to demonstrate the impact of particle size and NDF on total chewing time (TCT), eating and rumination, and milk fat content. The basic premise is that fiber in particles longer than 1.18 mm requires rumination and thus provides more rumen buffering through chewing and saliva production. peNDF can be calculated by multiplying the %NDF by the percentage of particles in a feed that are >1.18mm. It is recommended that feeds have a peNDF >21% to avoid milkfat depression.

Particle Size at Harvest

When ensiling forages, long, dry material does not pack well, as air does not get excluded sufficiently to optimize anaerobic fermentation. Thus, plant maturity affects not only NDFD when fed but also the ability to pack the forage dense enough to maximize exclusion of air.

When putting up dry hay, consider the influence of particle length and plant maturity on how long it will take animals to consume it and how long it will stay in the rumen. Low fiber digestibility feeds should be harvested in shorter particle lengths to minimize time for consumption and maximize surface exposure for microbial degradation. If possible, use hay processing knives when harvesting forages, especially mature forages as either dry hay or wet ensiled forage. This will help improve packing density, air exclusion, and reduce sorting optimizing DMI, rumen fermentation, and microbial yields.

It has long been thought that longer forage particles stimulate greater rumination than shorter particles. It turns out that particle size is but one variable in this concept. Fiber digestibility (NDFD) plays a significant role in determining rumination time. The less digestible the NDF (lower NDFD), the more time is required to chew and for microbial degradation for the forage particle to attain proper size and density to pass out of the rumen. Moisture content, particle size, and NDFD greatly influence the time required to ensalivate and create a swallowable bolus. Research has shown that the time required to consume a forage decreases with shorter particle size, and the particle length of the swallowed forage averages 10 mm regardless of the initial length. This does not suggest feeding only 10 mm-length forage; it demonstrates that feeding longer forage and longer low-digestibility forage increases chewing and rumination time, thereby limiting DMI and rumen fill.

Maintaining sufficiently long forage particles provides structure to the ruminal mat, allowing it to float and stimulate ruminal contractions needed to mix and move digesta out to the hindgut. Microbial degradation of forage fiber is generally from the inside out; microbes need access to the inside of plant cells to attach and degrade forage cell walls. Structural integrity of the forage matter needs to be disrupted to get past the protective outer layers. This requires rumination. Feeds that sink in the rumen compromise this structure and function. These silages tend to have undergone too long of an aerobic fermentation phase, as aerobic microorganisms can break the integrity of plant cells. They also tend to lack a clean cut on the forage ends which can cause them to absorb liquid, leading to faster sinking in the rumen. A simple way to test if silage is a "sinking silage" is to put a handful in a pail of water and see if it sinks. When sinking silages must be fed, they can be diluted with dry hay or other silage to maintain ruminal function; otherwise, milk potential can be lost.

Combining legume and grass forages can also help support healthy ruminal mat construction. If cows only eat highly digestible and very fragile fiber, it will be difficult to build a thick ruminal mat because the microorganisms will break down the fiber faster than the fiber can accumulate in the rumen. This will limit the growth of microorganisms, and thus the fermentation of feed, limiting nutrient availability to cows. Legume fiber digests quicker than grass fiber, as legume fiber is more fragile and tends to be higher in carbohydrates. Grass fibers tend to be more digestible than legumes at the same maturity level. Combining the two can help provide the balance necessary to create a healthy ruminal mat.

Estimating DMI, what animals should be eating and actually are eating, is a critical element of feeding all dairy animals, young calf, growing heifer, pregnant and lactating animals. Understanding and tracking DMI is critical for optimizing growth and productivity. Factors influencing DMI include metabolic requirements (maintenance, growth, pregnancy, and lactation), animal size (stature, large or small breed, and best estimated BW), feed quality (% NDF and digestibility), management (feed access and time budget for eating and resting), feeding frequency, and climate (temperature and humidity).

The baseline of DMI is meeting animals' metabolic energy and protein requirements. The limiting factor in meeting these requirements is whether the animal can physically consume sufficient feed or sufficient nutritional value to meet those requirements. Thus, the balance of energetic status and gut fill or rumen capacity helps determine BMI.

Animal size or BW is often used in equations to predict DMI. Size or stature dictates gut-fill capacity. Forage fiber (NDF) and fiber digestibility are also key determinants of gut fill and therefore daily DMI. The more digestible the fiber, the faster it degrades, ferments, and passes out of the rumen. The less digestible, the slower the degradation and passage, which results in prolonged rumen residence limiting further DMI. Table 16 shows ranges of DMI as %BW for both large and small breeds (NRC 2001).

	Growing			Pregnant & Dry		Lactating	
BW, kg	100	200	300	400	454	454	680
BW, lb.	220	440	660	880	1000	1000	1500
DMI, % BW	3.0	2.6	2.5	2.24	2.2	3.5-4.5	3.5-4.5

Table 16. Dry matter intake (DMI) estimates for cows at different stages and body weights (BW).

Feed access is a significant determinant of DMI. Tie-stall or individual feed access versus competitive eating scenarios of free stall bunks or round bale feeders influence DMI. Under competitive feeding conditions, timid or less dominant animals may not have sufficient feed access to fully meet their DMI needs. Feed access during times when animals desire to feed is also critical. Dairy animals generally prefer feeding at dawn and dusk.

Temperature and climate also influence DMI. Thermal neutral for dairy animals is between 5–20oC (41–68oF). Below 5oC, animals will increase DMI to meet increased energy needs. Under extreme cold conditions, DMI is not able to meet increased energy needs. As temperatures rise >20oC, DMI decreases. Increased humidity exacerbates the heat, resulting in a high thermal-heat index (THI) and reducing DMI while increasing energy expenditure of heat dissipation. At temperatures above 35o C (95oF), even water consumption decreases as animals expend energy panting to dissipate heat.

Time budget of conventionally managed TMR-fed lactating cows indicates 3-5 hours per day spent eating. Eating for longer than 5 hours cuts into rest and rumination time, social behaviors, milking time, and management time. Maximizing the quantity and quality of feed that can be consumed during this limited time frame is critical for the success of a grass-fed herd.

Monitoring Livestock Nutrition and Well-being

During the transition to grass-fed production, farmers should have a monitoring system in place to assure that herd health and body condition is maintained and that the herd is breeding on schedule. Changes in the quality of pasture and stored forages throughout the season will require farmers to monitor and adjust rations and herd management to maintain productivity, milk quality, and animal health.

Production

One quick way to assess the feeding program is to watch for variability in milk production, as drastic daily differences could indicate a problem. For example, in the winter employee error or a bad batch of hay could cause lowered milk production. During the grazing season, it is particularly important to note production changes in relation to pasture conditions. If there is a significant change in milk production, there may be differences in pasture quantity or quality at play. With careful tracking, adjustments can be made to benefit grazing management and animal performance.

Components and Milk Urea Nitrogen

It is important to monitor milk components, as these can also be influenced by the feeding program and animal well-being. Butterfat will decrease when the diet is high in unsaturated fatty acids. Although this is more typical of situations where the diet is high in concentrates and low in forage, access to lots of immature, lush pasture in a grass-based system can also depress milk fat. Butterfat can also be used in conjunction with protein to monitor for ketosis; if the fat:protein ratio is >1.4, the cow is at risk of ketosis because she is mobilizing her fat reserves for energy.

Another important monitoring tool is Milk Urea Nitrogen (MUN). As the protein in feed is digested in the rumen, ammonia is produced. Some ammonia can be utilized by ruminal microbes, but if there is too much ammonia, it can be absorbed through the ruminal wall and pass into the bloodstream. High concentrations of ammonia in the blood can be toxic, as it alters blood pH. To combat this change in pH, ammonia is transported to the liver, where it is converted to urea (a less toxic form of ammonia) to be excreted through urine and milk. MUN is the concentration of urea found in the milk and can be an indicator of inefficient nitrogen utilization. MUN levels also indicate the balance between protein and carbohydrates in the diet. MUN levels of 10–12 mg/dL are considered normal for lactating dairy cows. Levels below 8 mg/dL indicate protein deficiency and insufficient rumen N, whereas levels above 14 mg/dL may indicate excess protein or ruminal protein:carbohydrate imbalances. In the latter case, there may be insufficient energy via fermentable carbohydrates for rumen microbes to utilize the ammonia made available from the rumen RDP fraction. Both scenarios can decrease milk production and relate to additional health and performance issues. For instance, high MUN levels can be associated with reduced reproductive performance, including increased early embryonic death in cows, and thus result in extended calving intervals. In a study conducted in Ohio, Holstein cows with MUN levels below 10 mg/dL were 2.4 times more likely to be confirmed pregnant after the same number of services than cows with MUN above 15.4 mg/dL. For a grass-fed dairy herd, MUN can vary widely, and may be particularly high early in the grazing season when pastures are lush or have a high legume content, as these will be high in RDP.

Following are factors that can impact MUN:

- Feeding too much total crude protein in the ration can raise MUN.
- Feeding too much RDP and/or SP can raise MUN.
- Acidosis. Microbial growth will be inhibited, thereby increasing MUN.
- Breed. Holsteins usually have lower MUN values than other dairy breeds. However, this may be due to body weight rather than to a breed difference.
- Season. MUN values tend to be higher in months when the herd is grazing pastures commonly high in RDP.
- Sampling time. MUN values usually peak 3–5 hours after feeding.

If MUN levels fall outside the normal range, farmers should consider the following steps:

- If MUN is too high, check ration to determine if the crude protein is too high. If so, change to a different stored forage or consider some adjustment in the grazing system to allow a greater plant species mix or stage of maturity to provide a better balance of energy and protein.
- If MUN is too low, look at milk components to see if milk protein has decreased. A supplement with additional protein or changes to a different forage source to increase the soluble protein fraction may be needed.

While monitoring overall herd averages through bulk tank samples is important, joining monthly testing programs—such as the Dairy Herd Improvement Association (DHIA)—can be helpful in identifying issues with individual cows. Data collected on grass-fed dairy farms in the northeastern U.S. in 2018–2021 shows large variability in MUN across individual herds and among cows. The average MUN across these farms was 11.6 mg/dL. However individual cow MUNs ranged from 1–34 mg/dL. There were also differences by herd, with some herds averaging outside the ideal range over the entire period. On average, these herds experienced lower MUN levels in the winter months and higher levels through the summer months, increasing to the highest levels in late summer and early fall (Figure 14). However, not all herds follow this trend. Research into the drivers of MUN levels on farms in the northeastern U.S. began in 2021 but was not complete as of publication of this manual.

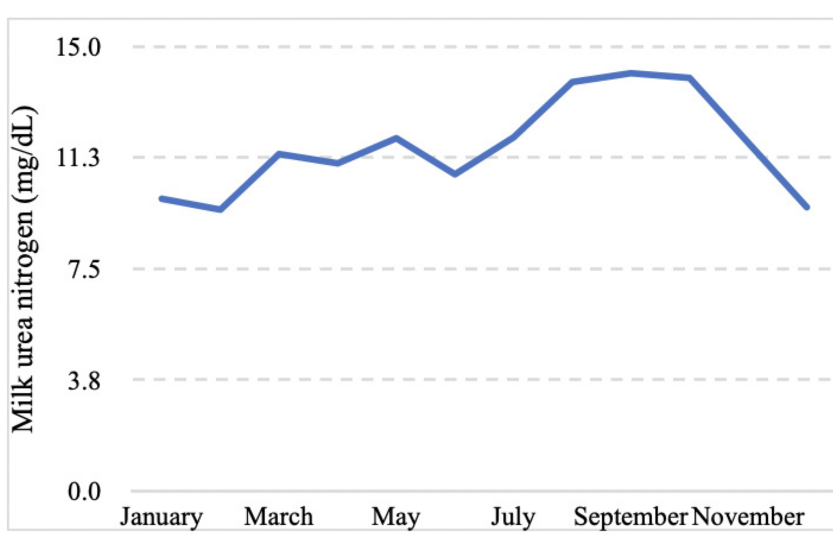

Figure 14. Milk urea nitrogen (MUM levels on grass-fed dairies throughout the year.

Source: Sara Ziegler, UVM Extension

Behavior

Observing the herd, both out on pasture and in the barn or barnyard, can provide helpful information on herd well-being and how effective the feeding system is. Consider the following:

- Is there enough head space at the feeders for every animal to be able to eat? Watch the first calf heifers or smaller animals carefully to make sure there is not competition for feed.
- Is the herd calm and do they lie down to ruminate once they are full?
- When moved into a new paddock, does the herd continue to search for adequate forage, or do they quickly settle down and graze? How quickly do they fill their rumens? If plant height, density, or palatability are poor, they may spend more time wandering and less time grazing.
- Are there signs of heat stress or agitation?

Growth and Stature

Body weight and height remain the primary means of assessing growth progression of an animal through stages of development and on to full maturity. There are numerous breed-specific growth charts to help monitor and track appropriate height and weight of growing animals. In general, goals of BW relative to fully mature BW are: 55% at breeding, 85% at first calving, 95% at second calving, and 100% or fully mature after third calving and lactation. Once mature body weight of healthy, non-obese animals is determined, BW of growth stages can be calculated using these values.

Farms using a grass-fed management system, in which w no grain can be fed to calves, typically feed milk for longer than a typical dairy farm. Since calves cannot be weaned from milk onto a grain/hay ration, feeding milk for 4 or 6 months is common, and some farms feed milk for longer than 6 months. Calves also need high quality digestible forages and a mineral source.

Body condition scoring through assessment of subcutaneous fat deposition is an essential management tool for assessing metabolic status, but it is not a good measure of growth or stature. Accumulation of excess body fat is detrimental to a dairy animal. By assessing bred heifers and dry cows, farmers can adjust feeding to ensure cows head into calving at the appropriate body condition. Excessive body fat will hinder body growth and possibly over tax the liver during the metabolic flux of lactation. For lactating cows, it is important to monitor condition in relation to their stage of lactation to ensure they do not drop to a condition beyond which they can recoup prior to dry off. Body condition for dairy cows is measured on a scale from 1–5, where 1 is excessively thin and 5 is excessively fat. Scores typically progress in increments of 0.25 or 0.50 to allow for more gradation. Ideally, year-round calving herds and seasonal herds between 150-175 days in milk should average a score of 3.00. A cow is scored by assessing the amount of fat covering and obscuring the view of her short and long ribs, hooks and pins, spine, and tail head. The less fat coverage, the more pronounced the bones will appear, and the lower the score will be. Scoring cows monthly or at least every few months will help identify feeding and other health-related issues before they progress. If farmers participate in a monthly milk testing program, the technician will know if body condition scoring services are available. Farmers can also score their cows themselves. Develop a system that is uniform throughout the herd, with set times of lactation that each cow is scored at (i.e., 120 days in milk and dry off). A helpful pictorial guide can be found in the resource list at the end of this chapter.

Manure scoring is another helpful management tool farmers can implement. Manure scoring can help identify problems in the balance between fiber, protein, and carbohydrates in feed and help determine if water intake is sufficient. This tool can be particularly helpful when cows are out on pasture, as it provides information about supplementation and access to water. Like the body condition scoring scale, the typical manure scoring scale is 1–5, where 1 is excessively loose and 5 is excessively firm (Figure 15). Manure that is the consistency of pudding, neither runny nor stiff, corresponds to a score of 3 and is ideal, as it indicates that the cow is receiving an adequate and balanced diet. Manure that is loose corresponds to a score of 1–2 and indicates excess protein or a lack of fiber in the ration. This tends to be the case early in the spring when cows are first let out onto pasture. If loose manure occurs later in the season, protein is likely too high or supplemental fiber is too low. Manure that is stiff and maintains more of a pile form corresponds to a score of 4–5 and is typical of heifers or other animals fed lower quality forage that contains more non-digestible fiber. Stiff manure in the lactating herd indicates a lack of protein in the diet. More information on manure scoring can be found in the resource list at the end of this chapter.

Figure 15. Manure scoring examples from 1 (left) to 4 (right).
Source: Sarah Flack

Energy Supplementation on the Grass-fed Dairy

One of the biggest challenges for grass-fed dairies is supplying adequate energy to the cows. As discussed previously, cattle derive energy predominantly from carbohydrates found in both the fibrous structure of plants (cellulose and hemicellulose) and inside plant cells (starch and sugar). Less mature plants contain more digestible fiber than fully mature plants, and the higher the amount of digestible fiber, the more energy the cow can get from those plants. This is also due to the increased rate of digestion that is possible with less mature plants. As forages become too mature, they develop more non-digestible fiber and thus become slower to digest, filling the rumen and limiting the total amount of feed and energy the cow can consume. Well-managed pastures are characterized by plants in vegetative stages that are highly digestible, high in protein, and high in sugar, but these plants are still low in energy relative to the amount of rumen, available N, and overall energy needs of the lactating cow. On an organic or conventional dairy, grain and other supplements would be used to correct this imbalance. But what are the options for grass-fed producers?

Current and prospective grass-fed dairy producers frequently ask the following questions:

- What energy supplements are available?
- Which energy supplements are allowed under organic grass-fed production?
- What is the limit on the amount of energy supplements that can be fed under grass-fed certifications?
- How do energy supplements impact milk production and quality?
- How do energy supplements impact cow health?
- How and in what quantity should farmers feed energy supplements?

This section summarizes current research-based information on energy supplementation to answer these questions. It is important to realize that, although these options may exist in the marketplace, there may be restrictions on types and amounts allowed by some certifying agents. In addition, the cost of some energy supplements may limit their use.

Molasses

Molasses is a high energy feed source derived from sugar cane. Unlike corn and other grains that are largely composed of starch, molasses contains sugar and many minerals and vitamins. Molasses is available in dried and liquid forms in both conventional and certified organic markets. In general, molasses has approximately 50–70% of the energy content of corn on a dry matter basis. However, availability, cost, and nutrient profile can vary slightly across regions and suppliers. Molasses often has added urea, which is not needed when feeding lush high CP grass and could be in excess of cows' microbial N needs and exacerbate MUN levels.

Although the energy content sounds appealing, does molasses work in practice? Since molasses is a sugar-based energy source, it is expected to impact ruminal fermentation differently than grain, which is higher in starch. However, laboratory research has shown little impact on ruminal fermentation and nutrient digestibility from additions of molasses to pasture-based diets at supplementation levels up to 10% of DMI and when fed in conjunction with both high- and low-quality forage. The research found that feeding molasses at 12% of DMI was comparable to the same level of corn meal supplementation in terms of milk production and components when fed through the grazing season. Molasses may also provide a better energy-to-protein balance than corn during the grazing season, as evidenced by lower MUN for cows fed molasses. These studies suggest that molasses can be an effective energy source for grazing dairy cattle without causing decreased ruminal function or milk production.

A 2018 survey of grass-fed dairies in the U.S. found that 54.3% of farms feed some energy source, most commonly molasses. Over 40% of these farms feed energy year-round, and approximately 30% feed energy as needed, either at strategic times of the year or to specific animals. On average, farms in the northeastern U.S. that feed molasses feed an average of 1.5 lbs. per cow daily. Farmers who indicated they supplemented energy also self-reported higher levels of milk production.

However, supplemental energy can be very expensive and thus increase the overall cost of production. Not all research suggests molasses as a cost-effective supplement for grass-fed dairies. Data on the cost of production of Northeast U.S. dairies in 2019 and 2020 showed significantly higher cost per hundredweight (cwt) on farms feeding molasses, and those farms did not sell more milk per cow than farms not feeding molasses. See chapter 5 for more information.

Although research suggests molasses can be an effective energy source, farmers should consider the following questions before using it.

- What is the goal in feeding molasses?
- How will it be fed to the cows?
- How much will it cost?
- How will its effectiveness be measured?

Molasses can be utilized in multiple ways, depending on the farm's goals and economics. Some farmers feed a little molasses just to entice the cows to come in for milking, while others use it to increase palatability and intake of low-quality stored forages or mineral mixes. Molasses can be top-dressed on forage, fed alone, or fed in a lick tub. Top-dressing forage is the most common method, as cows often don't like to eat straight molasses and tend to over-consume lick tubs, negatively impacting economics. Furthermore, handling molasses can be challenging, especially in the winter in northern climates. Dry molasses is an option, but it tends to be more expensive. Farmers should consider these factors and find what works for their farms. If starting to feed molasses, gradually introduce it like any other new feed source, and pay close attention to body condition, milk production, and milk quality. These indicators can help manage molasses feeding, identify potential problems, and help decide if it makes economic sense to continue.

Sugar

Dry sugar is another potential energy source. Like molasses, dry sugar largely has been used to top-dress feed to improve palatability and dry matter intake of poor-quality forage. Although it may be easier than molasses to handle on the farm, it could be more readily sorted from other feed.

Vegetable By-products

Some vegetables—including sugar beets, carrots, and cabbage—also have high sugar contents. Vegetable waste, most commonly in the form of beet pulp from sugar production or the processed vegetable industry, is often used as energy additive in grain. However, certified organic beet pulp is often difficult to source, and there has been little research in utilizing these by-products as energy sources for dairy cattle outside of grain-feeding systems. Feeding brassicas such as cabbage, kale, and turnips can impart off-flavors in milk if fed in too significant of quantities or too near to milking time.

Alfalfa Pellets

Alfalfa pellets are NOT a good energy source, but it is listed here since it is a commonly available supplement that grass-fed dairy standards allow. Some farms use it to keep cows coming into the parlor, increase mineral palatability, or increase ration protein. Caution should be used when supplementing with alfalfa pellets, as they are high in protein and potassium and may present ration imbalances, especially when fed during the grazing season.

Herd Genetic Selection Criteria Under Grass-based Diets

Farmers frequently ask about breed differences in suitability to grass-based systems. Successfully managed grass-fed herds include Holsteins, Jerseys, Guernseys, other breeds, and crossbreeds. No matter the breed, successful farmers make careful selections and cattle-purchasing decisions to assure their stock are well adapted to the unique needs of the grass-fed management system. For instance, grass-fed cows are often required to walk long distances to access pastures, spend much of the day grazing, and exposed to inclement weather or other environmental challenges not experienced by confined cows. Selecting for cows with traits that allow them to maintain production and health under these conditions is critical to success.

Genetic selection criteria used on well-managed grass-fed dairy farms frequently includes the following:

- Feet and legs are suited to walking distances daily to pastures.
- Wide muzzles and rumen capacity allow for efficient forage intake and digestion.
- Cows produce high butterfat milk, since most grass-fed milk buyers pay additional premiums for it.
- Cows have good milk production while maintaining body condition and reproductive performance.

Selection criteria can greatly influence cow productivity and performance. For example, North American Holstein-Friesian cows fed a grass-based diet showed significantly higher instances of mammary cell inactivity and thus lower productivity compared to New Zealand Holstein-Friesian cows. This can largely be explained by the different selection pressures between the variable pasture-based dairy systems of New Zealand and the high production-focused, concentrate-based systems in North America. These differing sets of selective pressures have given rise to production differences among these two genotypes.

Selection can incorporate off-farm genetics that are suited to the farm's system or the existing herd's successful animals. One example of on-farm selection is keeping replacement heifer calves only from cows that breed back quickly after calving. This way, the farm can build a herd comprised of animals that maintain body condition and breed back quickly without supplemental grain. It should be noted that not all differences observed between farms are due to genetic selection. Differences also may relate to learned behavior by the herd under different types of feeding or grazing management systems.

Reproductive Strategies on Grass-based Dairy Farms

A range of reproductive strategies are being implemented successfully on grass-fed dairy farms around the U.S. Successful reproductive strategies include altering herd seasonality and utilizing natural or artificial insemination techniques. Each farm must consider the factors that will be successful on their farm.

Seasonal Versus Year-Round Calving

In a year-round calving system cow groups are maintained on a rotating breeding schedule. This provides a relatively constant level of inputs, labor, and milk production on the farm. Conversely, seasonal calving requires synchronizing the reproductive calendar of the entire herd so that they all calve around the same time. Typically, grass-based farms use seasonal calving to align peak milk production with peak forage availability and quality. The typical program is for herds to calve in the spring, allowing for ample time after the grazing season concludes for cows to gain condition to a suitable level for calving again. A challenge with this system is the requirement that the herd be bred within a short window of time with little room for error. Therefore, one of the primary selection criteria in this system must be for cows that breed back on exactly a 12-month calving interval. This may mean culling higher-producing cows that don't breed back on-time and is likely a factor contributing to the lower production average on seasonal farms, as observed through recent research. This also means the farm is now on a seasonal milk production cycle, with the 2-month dry period occurring for all cows simultaneously. Here, farm economics are extremely important, and the milk buyer must be willing and able to accept milk in amounts that vary seasonally. Because milk price may vary seasonally and is typically lower in the spring than in the winter, this adds further financial disincentive to spring seasonal calving systems.

Artificial Insemination Versus Natural Service

Along with differences in breeding seasonality, there are differences in breeding techniques employed on grass-fed dairies. Typically, as farms focus on improving the genetics of their herd, they use artificial insemination to select semen from specific bulls with desirable traits. However, many grass-fed farmers continue to use natural breeding with bulls due to dissatisfaction with the suitability of available dairy semen and the superiority of bulls for heat detection for cows that are difficult to breed.

Measuring Reproductive Performance

Maintaining reproductive performance is a common challenge during the first few years of eliminating grain from the ration. If a farm transitions to grass-fed without a well-planned ration or feeding and management systems, the energy and nutritional needs of cows may not be met, and they may not cycle or breed. This can cause a drop in milk production; as more cows don't breed back on time and the whole herd shifts to being mostly in late lactation, there will be a larger-than-ideal number of open cows. This is a particularly critical issue in seasonal herds that rely on a short calving window. Monitoring and evaluating the success of the reproductive program is crucial to avoid such scenarios. Farmers may choose to use a herd record-keeping system or enroll through DHIA or other programs that can provide useful monitoring reports.

Days open are the number of days in the interval between calving and the subsequent pregnancy. This measure can help monitor how fast cows are able to breed back. If this interval becomes significantly extended, it can help identify potential issues with the breeding program and identify specific cows that may be having more trouble than others. Calving interval is the time measured from the birth of one calf to the birth of the next calf born to the same cow. It provides historical information for cows, allowing farmers to see if calving intervals change. Extended calving intervals are related to increased days open and indicate unsuccessful breeding attempts. It is important to note that some grass-fed herds have higher calving intervals for reasons other than poor reproductive performance. For instance, because of the relatively high price paid for grass-fed milk, farmers may find it economical to continue milking cows into longer lactations, when in conventional herds farmers would cull them. Calving interval and days open have significant lag time and so are better used to address overall breeding program success, not day-to-day progress.

Conception rate and services per conception are measures of the proportion of serviced cows that become pregnant, and the number of services required to achieve pregnancy. A decrease in conception rate will result in an increase in the number of services per conception, thereby impacting farm efficiency and economics. However, this does not account for all pregnant-eligible cows and is more a measure of heat detection and insemination success. Farmers enrolled in DHI testing will likely come across pregnancy rate on the summary report. This is the proportion of pregnancy-eligible cows that become pregnant within a particular 21-day period. and is the best way to gauge cow reproductive performance in real-time.

Preparing Cows for Reproductive Success

Farms that employ systems that adequately prepare cows for reproduction will have better success. Cows that calve with less-than-ideal body condition can have decreased ovarian activity during their first lactation, causing cows to take longer to ovulate, negatively influencing conception rates. Studies suggest that for every 0.5 unit of body condition lost between calving and insemination, a 10–15% reduction in conception rate can be observed. Particular attention should be paid to managing a dry cow ration that supports consistent dry matter intake leading up to calving and high intake following calving. This will minimize the change in energy balance that can be seen after calving. Furthermore, metabolic issues stemming from ration imbalances, such as milk fever or ketosis, are strongly associated with decreased immune function, increased susceptibility to infection, and subsequent decreased fertility. Using the previously mentioned herd monitoring tools is key to identifying ration imbalances that may impact reproductive success. Heat detection is particularly crucial on farms using artificial insemination, but heat detection is also important when using natural reproductive services. Accurately detecting the first heat following calving will help you time subsequent heats, minimizing days open and preventing calving intervals from becoming overly extended.

Youngstock Selection and Rearing

The decision about which heifer calves to raise, which management system to use to rear them, and how many calves to keep needs to be re-evaluated once a farm transitions to grass-fed. Selection of heifers kept and raised must be based on characteristics best suited for high forage diets: good feet and legs, ability to produce milk and hold condition, and ability to breed back on time on an all-forage ration.

Calves not fed any grain will be fed more milk; this additional need for milk combined with the lower milk production overall can contribute to much less milk sold per cow per year. At the same time, raising more heifers than needed to meet replacement needs can contribute to a higher cost of production.

Unless there is a known market for grass-fed replacements paying at least what it costs to raise them, a better strategy is to raise heifers only from the herd's best cows. Raising a small group of heifers each year also makes it easier to manage them carefully, monitor for any health issues, and provide them with high-quality digestible forages and minerals.

The financial impact of raising more youngstock than the farm needs can be calculated by looking at the total cost of milk, minerals, and forages consumed. It can also be helpful to examine just the additional forage and acreage needed to support a larger group of heifers.

Example: Dry Matter Intake Needs with Farm-based Reproduction Strategy

In previous 60-cow farm examples, the farm was keeping 15 calves per year and needed 550 total tons of DM per year to support the herd. If the farm instead raises most of the heifer calves, total forage needs increase to 623 tons, meaning that the farm will be short 251 tons of DM per year due to the additional forage needed support these additional youngstock.

Table 17. Dry matter intake needs.

Animal Group	No. Cows	BW, lbs	DMI, lbs.	DMI, %	Days Fed	Tons
Lactation Cows	60	1200	42	3.5	305	384
Dry Cows	60	1200	24	2.0	60	43
Heifers Pregnant	29	800	18	2.3	365	95
Heifers Growing	19	400	10	2.5	365	35
Heifers Young	10	200	5	2.5	365	9
Total						567
Total, with 10 % waste						623

Table 2. Dry matter from forage produced.

Forages Grown	Acres	DM T/A	DM T/yr.	
Pasture	70	1.75	123	
Hay Fields	100	2.5	250	
Other	0			
Total			373	
Net: (required minus grown)			251 short	

KEY POINTS

- The goal of herd management is to meet the basic needs of the cow to support maximum milk production and quality.
- Rumen is the major component of the digestion physiology of a cow; it houses a symbiotic relationship between the cow and rumen microorganisms. Fermentation of fiber and carbohydrates for energy and growth of microbes provide a significant portion of proteins/amino acids to the cow.
- Four types of protein are important to the cow: crude (total protein in the feed), bypass (rumen undegraded protein, RUP), degradable (rumen degradable protein, RDP), and soluble (can be quickly dissolved and utilized by rumen, SP)
- It is critical to balance fiber in the cows' diet. Too little fiber will cause the rumen to become too acidic, too much fiber will reduce production and overall health.
- Major minerals required by cows are Ca, P, Mg, K, Na, Cl, S. Required trace minerals are Co, Cu, I, Fe, Mn, Mo, B, Se. Required vitamins are A, E, D.
- Water is among the most important components of a cows' diet. Sufficient intake is essential for digestion and milk production.
- One of the biggest challenges for grass-fed dairies is supplying adequate energy to the cows.
- The Net Energy of Lactation is the total energy required by the cow for bodily maintenance and milk production. Metabolizable energy is becoming a more accurate evaluation of energy use by the animal and value of feeds.
- Supplemental energy sources include molasses (high energy source derived from sugar cane), sugar, and vegetable by-products such as pulp from sugar beets.
- Molasses is often used to encourage cows to come into the barn, increase palatability and intake of low-quality stored forages, and increase intake of mineral mixes to required levels.
- During the transition to grass-fed, farms should have a herd health/body condition monitoring system.
- When feeding forages, be mindful of differences in methods of mixing, measuring, frequency, and timing.
- Pasture conditions during the grazing season can cause differences/variance in milk production.
- Monitor overall herd health/averages through bulk tank samples, monthly testing programs (for example, DHIA), cow behavior and movement, rumen fill, body condition, and manure texture.
- Milk Urea Nitrogen (MUN) levels help identify inefficient nitrogen utilization and monitor imbalances between protein and carbohydrates in the diet.
- Breed/cow selection criteria include feet and legs suited for walking distances, wide muzzles and rumen capacity, high butterfat milk, and good milk production.
- Seasonal calving is a reproductive strategy that can help align peak milk production with forage • availability.
- Metrics for reproductive performance include days open, calving interval, conception rate, and services per conception.
- To manage youngstock, farmers should make careful selection of which heifers and how many to keep, allocate high quality forages, institute a mineral program, and feed milk for 4–6 months.

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CHAPTER FIVE

Financial Pros and Cons of Grass-fed Dairy

Before assessing how the cost of production will change on an all-forage ration, it is important to understand the farm's current financial health. Knowing current cost of production data will make it easier to compare changes in costs and how management decisions impact profitability. For more information on assessing farm profitability and cost of production, see the resources listed at the end of this chapter.

Transitioning from grain-feeding to grass-fed impacts each farm's finances differently, depending on how large the reduction in milk production is, which farm expenses change and by how much, and what changes in reproductive performance and herd health occur. Most farms see a significant increase in cost of production as they convert to grass-fed management.

Although some milk buyers pay a premium for grass-fed milk which may cover at least a portion of this increased cost, those premiums are not available in all areas. In addition, the premium for grass-fed milk may not cover the additional cost of production.

Research in the Northeast was conducted on data from 21–24 grass-fed dairy farms collected annually over a three-year period (2018–2020). The data, compiled using DairyTRANS, showed an average cost of production of $49.95/cwt equivalent. This is at least $12/cwt over the cost that most grain-feeding organic farms in the same region during the same time.

Income Changes Under Grass-fed Management

In planning a transition to grass-fed, one of the most difficult parts is predicting and managing the reduction in milk production. Farmers reported reductions ranging from 25–40%.

The example farm discussed previously in this report, may choose to stay at 60 cows during their grass-fed transition, or they may possibly downsize further to better match their grass-fed herd's forage intake needs to the land base. This would require the farm to conduct a financial analysis to assure that the smaller amount of milk being shipped will cover the farm's expenses.

In addition to lower milk production per farm, some farmers report that cow calving intervals increase. This can lead to more late lactation cows in the herd, further depressing milk yields. This highlights the importance of selecting for cows that maintain a certain level of milk production and reproductive performance in a grass-fed production system.

Example: Maintaining Milk Production with Grass-fed Herd

In the 60-cow farm example farm, if this farm experienced a 40% reduction in milk production as they transitioned to grass-fed, they would need to add 24 cows to maintain the previous milk production level. However, on the 170 acres of land the farm has, it may be difficult to meet the desired grass-fed pasture dry matter intake level of 84 cows plus additional youngstock (Table 19). The farm also would need to produce more forage on additional land or to buy additional forages, may be short on space in the barn, and would see increased variable costs for items such as minerals, bedding. Overall, the farm would require 219 additional tons of forage dry matter needed per year, so the farm would be short a total of 396 total tons per year (Table 20). The additional forage would have to purchased or made on additional leased or purchased land.

Table 19. Dry matter needs with more cows.

Animal Group	No. Cows	BW, lbs	DMI, lbs.	DMI, % BW	Days Fed	Tons DM/yr.
Lactation Cows	84	1200	42	3.5	305	538
Dry Cows	84	1200	24	2.0	60	60
Heifers Pregnant	21	800	18	2.3	365	69
Heifers Growing	14	400	10	2.5	365	26
Heifers Young	7	200	5	2.5	365	6
Total						299
Total, with 10 % waste						769

Table 20. Dry matter from forage produced.

Forages Grown	Acres	DM T/A	DM T/yr.
Pasture	70	1.75	123
Hay Fields	100	2.5	250
Other	0		
Total			373
Net: (required minus grown)			396 tons short

Example: Forage Requirements and Pasture Size Limitations

Looking at the 60-cow example again, if the farm now must increase the amount of forage intake from pasture during the grazing season from 50% to 80% to meet the herd's intake goals, this will add approximately eight-tenths of an acre to the daily paddock size required for the milking herd. Over the whole grazing season, this can increase the total acreage needed in the grazing rotation from 25 acres to over 40 or more acres depending on the land base and local climate. If this farm cannot access more land, they may instead need to downsize the herd. For example, if they have 70 acres of pasture, and some of that is grazed by heifers, they may have to consider reducing the herd from 60 cows to about 50 cows, and they will also need to graze some hayfields after first or second cut to assure sufficient pasture intake to meet their goals.

Expenses that Commonly Change Under Grass-fed Management

Change to grass-fed management eliminates the cost of grain, but other expenses usually increase, including the following:

- Minerals and energy supplements
- Purchased forage
- Land cost to provide more forage
- Soil amendments

One of the biggest factors in expense changes under grass-fed management relates to forage availability. One of the biggest factors in expense changes under grass-fed management relates to forage availability. Data from grass-fed farms in the Northeast U.S. consistently shows farms using an average of 5.5 acres per mature cow; this increases to 6.8 acres per mature cow to produce enough quantity and quality of pasture and stored forage for farms raising all their own forage. If the farm does not have a large-enough land base to support the increased forage demand, or if it does not have enough pasture within cow-walking distance of the barn, additional land will need to be acquired. Alternatively, more forage can be purchased from off the farm. This will increase purchased feed expenses and removes the farmer's control over forage quality.

Some farms can manage with less than the average acres per mature cow. Strategies to be able to meet forage intake requirements on a smaller acreage include increasing yield per acre through improved forage varieties, stand density, and soil fertility, and by only raising the number of replacements needed. See also the farm examples in chapters 3 and 4.

As discussed in chapter 4, mineral supplementation for the grass-fed herd is essential to maintaining production, reproductive performance, animal health, and ultimately farm success. Once minerals are not being fed through grain, a separate loose mineral mix must be purchased, and a mineral feeding system decided upon and possibly purchased. Similarly, expenses related to importing and applying soil amendments will need to increase to combat soil nutrient depletion.

Overall, most farms report that their cost of production increases under grass-fed management. Each farm has its own set of unique resources and challenges, so what works on one farm may have different financial outcomes on the next farm.

KEY POINTS

- Overall, most farms report that cost of production increases under grass-fed management.
- Knowing current cost of production will make it easier to compare changes in costs and how management decisions affect profitability when transitioning to a grass-fed system.
- Transitioning to grass-fed management can impact finances in relation to milk pay price, changes in milk production, changes in farm expenses, and changes in reproductive performance/herd health.
- Expenses likely to increase include mineral and energy supplements, purchased forage, land rental or purchase, and soil amendments.
- In the Northeast U.S., grass-fed cows use an average of 5.5 acres per mature cow and farms raising all their own forages use 6.8 acres per mature cow. Some farms may need to either increase acreage or decrease herd size.
- Farmers have reported a 25– 40% reduction in milk production after transitioning to grass- fed.
- Selecting cows that maintain production and reproductive performance in a grass-fed system and an adequate supply of high-quality, high-energy forages are keys to keeping the cost per cwt as low as possible.

CHAPTER SIX

Conclusion

Success with grass-fed dairy management requires excellent management skills and a well-thought-out plan. Key factors for success include producing (or buying) high quality (high energy) forages AND maximizing forage dry matter intake. Increasing the acreage, purchasing more forages, or decreasing herd size may be necessary when converting to a fully grass-fed system. By raising only the number of calves needed for replacement rates on a milk/high quality forage ration, farms may increase the amount of milk that can be sold per year and decrease the number of acres needed for hay and pasture. Changing herd genetics and selection criteria may also be needed. Careful monitoring of herd health is essential.

Approach to maximize forage intake and maintain herd performance, wellbeing, and milk production vary greatly by farm. Although some management practices are shared by successful grass-fed farms, overall, there is a wide range of grass-fed management practices. Connecting with other grass-fed dairy farmers to learn from one another is often a very successful approach to discovering what works best, as each farm needs to find their own "best" systems. Some farms may find that being grass-fed is not a good match for them, while others will find that grass-fed management is well suited to their farm.

Summary of Suggestions for Grass-fed Dairy Farmers

- Larger amounts of forage per cow will be needed. Increase forage through the following actions.

  Add more land to the pastures as paddock sizes increase.

  Add more land for harvested and stored forages or buy more high-quality forage.

  Improve forage yields.

- Maximize dry matter intake of forages through providing highly digestible high-quality forages.

  Look for lower NDF values on forage tests with high energy and enough (but not too much) protein.

  Higher digestibility is necessary to allow cows to eat a larger quantity of forage to replace the nutrition they were previously obtaining through grain.

- Improve forage quality through the following tactics.

  Improved plant species.

  Earlier harvest.

  Improved harvesting and storage methods.

  Improving soil fertility.

- Whole farm nutrient balance management likely will require more off-farm fertility inputs.
- Feed enough of the right types of mineral supplements. Forages will not be able to provide all the minerals needed by the herd.

- Manage pre-fresh cows and heifers carefully to improve milk production.
- Decrease competition for feed and manage feeding so that all cows and youngstock have access to highly digestible forage, water within easy walking distance, and adequate minerals.
- Monitor herd performance and well-being systematically. This includes the following strategies.

  Monitor body condition/

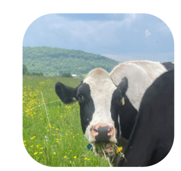
  Monitor ruminal fill constantly.

  Manure scoring/

  Monitor MUNs.

  Monitor reproduction.

  Carefully plan youngstock management system.
- Select for the right herd genetics.
- Consider raising fewer replacement cows.
- A thorough assessment of the farms' current cost of production and the impact transitioning to grass-fed will have on farm finances is crucial.
- Make sure that the level of milk production with no grain will provide enough income to keep the farm financially sustainable.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