A Blueprint for Evaluating Feeding Programs

Michael F. Hutjens

Department of Animal Sciences, University of Illinois, 232 ASL, 1207 West Gregory Drive, Urbana, IL 61801
Email: hutjensm@uiuc.edu

Take Home Message

- Monitoring milk yield and components reflect nutrient balance
- Feed particle size is critical for health and optimal production
- Blood, milk, and urine measurements can identify metabolic risks
- Feeding program economics are key to profitability

Dairy managers and cows make feeding changes on the farm. Some changes are intentional (such as reformulation of rations) while others "happen" (such as heat stress). The skilled manager, feed consultant, and veterinarian are continually evaluating and "reading" cows. On-farm records can be used to monitor changes, evaluate responses, and determine economic comparisons of feeding programs (Jordan and Fourdraine, 1993). Each person should develop her or his record evaluation approach and checklists to implement on the farms they serve.

Using Milk Production Records

Milk production records continue to be a valuable tool to evaluate nutritional changes and responses. Several different aspects can be evaluated (Hutjens, 2001).

Management level milk (MLM), managed milk, or 150-day milk converts milk production to a common base: 150th day of milk production, same lactation number (usually second lactation), and the same milk components (fat and protein). If MLM changes due to a ration change, the impact of longer days in milk, freshening patterns, age of cows, and component changes are corrected. Thus, the dairy manager can evaluate if the feeding change has had an impact.

As a guideline, a shift of one kilogram in MLM due to the feeding change may be significant.

Profiling milk yield by days in milk (DIM) and lactation number are excellent ways to recognize feeding and management deficiencies or imbalances. Table 1 lists guideline values for Holstein cows summarized by Mid-States DHI records in 1993 (no impact of BST was possible in this data set).

Table 1. Milk production profiles for Holstein herds (Source: Mid-States DHI).

Milk yield (kg)	Lactation (number)	Summit milk (kg)	< 50 DIM	50 to 100 DIM	100 to 200 DIM	> 200 DIM
10,455	1	34	64	72	69	61
	2	44	86	90	79	62
	3 +	47	89	95	85	65
9,545	1	31	59	66	63	54
	2	40	80	83	72	56
	3 +	44	81	88	77	59
8,636	1	29	56	61	57	49
	2	37	73	76	66	51
	3 +	40	76	80	70	53
7,727	1	27	52	56	52	44
	2	34	67	68	59	45
	3 +	36	70	73	64	48

Dairy managers and nutritionists can plot milk yield to determine if cow groups (based on DIM) shift profile guidelines as their lactations continue. Impact of previous lactation can also be evaluated (such as sophomore slump). This analysis can also measure response to BST. The following groups and feeding interpretations could be considered.

- 0 to 50 DIM — Transition cow management; Dry matter intake prepartum and postpartum; Metabolic disorders
- 50 to 100 DIM — Body condition changes; Level of dry matter intake; Impact of ketotis and acidosis; Lack of amino acids (protein shortage)
- Over 100 DIM — Dry matter intake relationship to milk yield; Low body condition score (energy shortage); Ration nutrient density and sources

Summit milk yield is the average of the highest two milk weights collected in the initial three measurements on DHI test. While this value is similar to peak milk, summit milk reflects the shape of the milk production curve in early lactation. Table 1 lists summit milk based on lactation number and days in milk. Multiplying kilograms of summit milk by 102 (some individuals will use 91) can provide an estimate on the amount of milk that can be produced in the total lactation. The time when peak milk occurs should be 50 to 70 days after calving (50 to 100 DIM in Table 1). If peak milk occurs earlier or later than this time period, true peak milk may not have been achieved.

Milk fat test patterns can reflect changes in rumen pH, nutrients delivered in the ration dry matter, and shifts in body weight loss. Table 2 lists normal breed component values.

Table 2. Normal milk fat and milk protein relationship for various breeds of dairy cattle in 1999 (adapted from Hoard's Dairyman, 2000).

Breed	Milk Fat	Milk Protein	Ratio
	(%)	**(%)**	**(% protein / % fat)**
Ayrshire	3.86	3.32	0.86
Brown Swiss	3.95	3.44	0.87
Guernsey	4.42	3.49	0.79
Holstein	3.66	3.15	0.86
Jersey	4.57	3.73	0.82

Evaluate milk fat profiles by lactation number and days in milk. The following days in milk can provide clues to feeding effects related to milk fat test.

- Less than 50 days in milk. High milk fat tests (over 1.0 percentage point above breed average such as 5.6 for Jersey cows) reflect excessive weight loss. Low fat tests can reflect energy shortages.
- From 50 to 150 days in milk. Milk fat test will be at their lowest point unless negative rumen effects have occurred. For high producing Holsteins, a milk fat test between 3.0 to 3.3 percent is not a concern.
- From 150 to the end of lactation: Milk fat should be normal for the breed (Table 2).

Milk protein test patterns should follow milk fat test patterns listed above. Breed averages for 1999 listed in Table 2 reflect total protein values (0.19 units higher than true protein initiated in 2000). If milk protein tests are below breed average or the ratio of milk protein to milk fat is below breed average, the genetic protein level is not being achieved. The following areas should be reviewed if milk protein tests are too low.

- The amount of fermentable carbohydrate is low reducing microbial protein production. Evaluate levels of starch, sugar, and fermentable fiber.
- Evaluate the level of total protein, levels of rumen degradable and undegradable protein, and amino acid balance.
- Determine if rumen factors may be limiting microbial growth (such as rumen acidosis).
- Feeding unsaturated and rumen unprotected fats and oils can reduce milk protein test. Total milk yield may have increased while total amount of protein remains constant.
- Low ration dry matter intake and digestibility can reduce microbial yield and intake of undegradable protein.

The ratio of milk protein to milk fat can be used to determine if milk fat depression has occurred. Milk fat inversions can be defined as when individual cows have milk fat tests that are less than 0.2 points below milk protein tests. For example, a Holstein cow with a 3.0 percent milk protein test and 2.8 percent milk fat test or lower would be inverted using the current true protein test. Before 2000, milk protein was 0.19 units higher because milk was tested for total protein. The following guidelines can be used to determine whether a feeding practice has led to a milk fat test inversion.

- If over 10 percent of the cows in the herd have milk fat inversions greater than 0.2 points.
- Cows one full point below the breed average milk fat percent.

Evaluating Blood Values

Wisconsin workers have developed guidelines on biological tests that could be conducted on a herd to evaluate nutrition related problems (Oetzel, 2000). Two types of tests can be used. Tests can be used to determine the proportion or percent of cows in the herd being affected (requires a minimum of 12 cows) including rumen pH, plasma fatty acids, and blood ketones. The second group of tests can be used to determine the herd average occurrence of the problem (requires 8 or more cows) including urine pH (with feeding anionic salts) and milk urea nitrogen.

Rumen pH

Rumen pH is measured by testing 12 or more cows four hours after eating using a rumen tape or rumenocentesis (a needle is inserted in the lower left side of the cow and a small sample of rumen fluid extracted). If over 25 percent of the cows have rumen pH values below 5.5, sub-acute rumen acidosis (SARA) may be occurring.

Serum beta hydroxybutyrate acid (BHBA)

Serum beta hydroxybutyrate acid (BHBA) is measured by taking a blood serum sample from cows 5 to 50 days after calving at 4 to 5 hours after eating a meal. Serum level over 14.4 mg per deciliter in 10 percent or more of the sampled cows indicated sub-clinical ketosis (values over 26 are ketotic cows). Sub-clinical ketosis could reflect a poor transition cow program, low dry matter intake, heavy cows, and/or metabolic disorders.

Plasma non-esterified fatty acids (NEFA)

Plasma non-esterified fatty acids (NEFA) reflect if cows are mobilizing body weight to meet energy shortages. Blood is taken from cows 2 to 14 days before calving. Test those cows that actually calve 2 to 4 day prepartum (cows do not calve on time and blood samples can not be taken if the cow has calved early). Sample cows just prior to the main feeding. If greater than 10 percent of the 12 cows sampled are over 0.400 milliequivalent per liter, a potential energy deficiency may be occurring in the herd leading to metabolic disorders.

Urine pH

Urine pH from cows receiving anionic products to prevent milk fever and minimize hypocalcemia (low blood calcium) should average 6.0 to 6.5 for Holstein cows. Collect urine samples after cows were fed anionic products for a minimum of 2 to 3 days. Sample a minimum of eight cows at four to eight hours after the cows have consumed feed (especially if dry cows are fed once a day).

Milk Urea Nitrogen (MUN) or Blood Urea Nitrogen (BUN)

Milk urea nitrogen (MUN) or blood urea nitrogen (BUN) reflects if an optimal balance of protein (especially degradable and soluble protein fractions) and fermentable carbohydrate occurs. Sample eight cows per group to determine if the average is between 12 to 16 milligrams per deciliter for MUN or BUN. For

BUN analysis, sample 2 to 4 hours after a major meal has been consumed. Looking at groups of 8 to 10 cows (by lactation, days in milk, feed group, or level of milk production) should be used to evaluate MUN values.

Measuring Feed Particle Size

Illinois workers use the following set of sieves to measure corn particle size (Hutjens, 2001).

- Top screen (number 4 and 4750 micron) captures whole and large particles
- Second screen (number 8 and 2360 microns) represents cracked corn
- Third screen (number 16 or 1180 micron) represents "cow" corn particles
- Fourth screen (number 30 or 600 micron) represents "pig" corn particles
- The pan which represents powder or feed grade starch

In a typical Midwest ration containing hay, haylage, corn silage, and typical concentrate level, no dry corn should appear on the number 4 screen (passes undigested), less than 10 percent on the number 8 screen, 25 to 35 percent on the number 16 screen (slow released starch in the rumen and small intestine digestion), 50 to 60 percent on the number 30 screen (finely ground feed for rumen fermentation) and less than 15 percent in the pan (rapid available starch for the rumen microbes). If the ration contains higher levels of wet haylage, lower amounts of corn, and by-product feeds, the corn particle size could be reduced. Reducing corn particle size will increase the risk of rumen acidosis. Brass U.S. Standard sieves can be purchased from Fisher Scientific (800-766-7000) or Seedboro Equipment Company (312-738-3700). Prices will vary from US $200 to $260 per set of five. Another approach to measure finely ground corn is to use a flour sifter (similar to a number 14 or 16 screen) to estimate particle size. Finely processed corn will have one third remaining in the flour sifter (two thirds will pass through).

Measuring forage particle size using the Penn State particle boxes continues to be a popular way to objectively evaluate if forage and TMR have optimal forage particle size. Place a 200 to 300 gram sample in the box and shake until all feed has been exposed to the holes in each box. Compare the weight in each box to the guidelines in Table 3. Recent field observations indicate if the top screen in TMR is over 15 percent, cows may sort the ration. To calculate the amount of effective fiber, subtract the percent in the bottom box from 100 and calculate the amount of effective NDF contributed by silage by multiplying the kilograms of silage dry matter times the percent silage NDF times the percent silage in the top and middle box. Feed particles in the middle box may be more important than the top box only. The Penn State box can also be used to evaluate weigh back or orts to determine if feed sorting has occurred. One guideline is the percent of feed in each box in the weigh back should be plus/minus five percentage points of the original TMR

Table 3. Penn State particle size box guidelines expressed as the percent in each box on an as fed basis.

Feed measured	Top	Middle	Box
	------------------ % of total -------------		
Total mixed ration	8 to 15	35 to 45	< 50
Haylage	> 20	30 to 50	< 40
Corn silage (3/4" TLC, processed)	10 to 20	40 to 60	< 35
Corn silage (3/8" TLC, unprocessed)	< 5	> 50	< 50

▪ Manure Evaluation

Dairy managers watch manure changes as a guide when making feed changes. Fresh, undisturbed piles of feces or droppings may provide valuable clues on the nutritional status of the cow. Three aspects of manure evaluation can be considered (Hutjens, 2001).

Washing Manure

Washing manure through a screen (6 to 8 squares to the inch) allows the dairy manager to quickly find or "see" if feed processing and digestion is optimal. Take a cup of fresh manure and wash it with a stream of warm water (cold water takes longer) through the screen removing the digested material. It typically takes about 30 seconds if your screen has sides allowing for more water pressure. Look for the following remaining feed particles. Finding pieces of barley or corn grain with white starch remaining indicates that some feed value was lost. If the seed and starch pieces are hard, additional grinding or processing may be needed to expose the starch to rumen microbial fermentation or lower gut enzymatic digestion. Corn kernels from corn silage reflect that the seed was too hard for digestion and chewing by the cow. Mature and dry corn silage can cause this observation as grain is hard. Some corn silage varieties can be selected for softer kernels allowing for more digestion. Whole cottonseeds or soybean splits (half of a soybean seed) that appear in the washed manure reflect a loss of feed nutrients. The cottonseeds are not caught in the rumen mat and do not allow for rechewing. If roasted soybean seeds are hard, they must be processed finer. Wisconsin workers suggest breaking soybeans into fourths or eighths. Forage particles over ½ inch long may reflect a lack of long forage particles to maintain the rumen mat and adequate cud chewing. A higher rate of passage reduces the time needed in the rumen to digest the fiber properly.

Scoring Manure

Michigan workers developed a scoring system to evaluate fresh manure (Hutjens, 2001). Consistency is dependent on water and fiber content of the manure, type of feed, and passage rate. A scale of 1 to 5 is listed below with a score 3 optimal.

- Score 1. This manure is very liquid with the consistency of pea soup. The manure may actually "arc" from the cow. Excess protein or starch, too much mineral, or lack of fiber can lead to this score. Excess urea in the hindgut can create an osmotic gradient drawing water in the manure. Cows with diarrhea will be in this category.
- Score 2. This manure appears runny and does not form a distinct pile. It will measure less than one inch in height and splatters when it hits the ground or concrete. Cows on lush pasture will commonly have this manure score. Low fiber or a lack of functional fiber can also lead to this manure score.
- Score 3. This is the optimal score! The manure has a porridge-like appearance, will stack up 1 ½ to 2 inches, has several concentric rings, a small depression or dimple in the middle, makes a plopping sound when it hits concrete floors, and it will stick to the toe of your shoe.
- Score 4. The manure is thicker and stacks up over 2 inches. Dry cows and older heifers may have this type of manure (this may reflect that low quality forages are fed and/or a shortage of protein). Adding more grain or protein can lower this manure score.
- Score 5. This manure appears as firm fecal balls. Feeding a straw-based diet or dehydration would contribute to this score. Cows with a digestive blockage may exhibit this score.

Manure scores 1 and 5 are not desirable and may reflect a health problem besides dietary limitations. Score 2 and 4 manure may reflect a need to rebalance the ration. As cows progress through their lactation, manure score may also shift as outlined below.

- Fresh cows (score 2 to 2 ½)
- Early lactation cows (2 ½ to 3)
- Late lactation cows (3 to 3 ½)
- Far off dry cows (3 to 4)
- Close up dry cows (2 ½ to 3 ½)

Increasing the amount of degradable, soluble, or total protein, deceasing the amount or physical form of the fiber, increasing starch level, decreasing grain particle size (such as fine grinding or steam flaking), and consuming excess minerals (especially potassium and sodium) can cause manure scores to decline.

Manure Color

The color of manure is influenced by feed, amount of bile, and passage rate. Manure from cows on pasture is dark green while hay-based rations are brown. Manure from high grain-based diets are more gray-like. Slower rates of passage cause the color to darken and become more ball-shaped with a shine on the surface due to mucus coating. Score 1 may be more pale due to more water and less bile content. Hemorrhage in the small intestine causes black and tar-like manure while bleeding in the rectum results in red to brown discoloration or streaks of red.

▪ Evaluating Silage Fermentation

To evaluate silage fermentation, dairy managers and consulting nutritionists can send a sample of silage to commercial labs. Optimal fermentation profiles are summarized in Table 4. The cost of this analysis will range from US $20 to $30 a sample. By evaluating the fermentation characteristics, forage quality at ensiling, moisture content, and silage storage characteristics can be evaluated and improved next year. Levels of acetic acid increase as dry matter content drops. Higher levels of butyric acid indicate a fermentation problem. While higher lactic acid is considered "desirable" fermented silage, it may not prevent aerobic secondary fermentation. A certain amount of acetic acid is desirable to minimize possible yeast and mold organism growth. High levels of butyric acid contribute to an aerobic environment. Wisconsin workers reported that wet haylage can contain 0.5 to 1.5 percent butyric acid on a dry matter basis. Butyric acid is an undesirable volatile fatty acid (VFA) produced during poor silage fermentation (Oetzel, 2000). The butyric acid is consumed by the cow and converted to beta hydroxybutyric acid (BHBA) leading to ketosis and metabolic disorders. If cows consume over 50 grams of butyric acid (for example, 10 kilograms of haylage dry matter containing 0.5 percent butyric acid on a dry matter basis would provide 50 grams of butyric acid), animals are at risk. Higher levels of ammonia and other nitrogen compounds may exist reducing forage quality in these high butyric acid silages. Clostridium organisms can exist when unfavorable fermentation patterns (pH over 5) and higher butyric acid levels occur. Butyric acid can be a “marker” of poor silage quality.

Table 4. Recommended fermentation profile for ensiled feeds (Source: Taysom, 2000).

Measurement	------ Legume/grass mixture-----			Corn Silage	H.M. Corn
Dry matter (%)	<35	35 to 50	>50	35 to 40	70 to 75
PH	4.0 to 4.3	4.3 to 4.7	4.7 to 5.0	3.8 to 4.2	4.0 to 4.5
Lactic acid (%)	6.0 to 8.0	4.0 to 6.0	2.0 to 4.0	5.0 to 10.0	1.0 to 2.0
Acetic acid (%)	1.0 to 3.0	0.5 to 2.5	0.5 to 2.0	1.0 to 3.0	< 0.5
Propionic acid (%)	< 0.5	< 0.25	< 0.10	< 0.10	< 0.10
Butyric acid (%)	< 0.5	< 0.25	< 0.10	< 0.10	< 0.10
Ethanol (%DM)	< 1.0	< 1.0	< 0.5	< 3.0	< 2.0
Ammonia (% CP)	< 15.0	< 12.0	< 10.0	< 8.0	< 10.0
Lactic/Acetate	> 2.0	>2.5	> 2.5	> 3.0	> 3.0
Lactic (% total)	> 60	> 70	>70	>70	> 70

▪ Evaluating Dry Matter Intake

Evaluating nutrient changes in the feeding program is a common approach to evaluating milk responses. The following guidelines can assist dairy managers to determine if their feeding programs are optimal. Dry matter intake guidelines can be a key factor to compare and evaluate nutritional changes (Hutjens, 2001).

- For each 0.45 kilogram of additional dry matter intake (above current intake), milk production increases by one kilogram.
- The initial 5 to 6 kilograms of dry matter intake consumed by Holstein cows are needed to meet the maintenance energy requirements (10 Mcal of net energy). Subtracting 6 kilograms of dry matter from total dry matter intake calculates energy available for milk production. Multiply the remaining dry matter by 2 to estimate milk production potential. For example, a high group of Holstein cows consuming 24 kilograms of dry matter can support 36 kilograms of milk (24 kg of DM - 6 kilograms of DM for maintenance equals 18 kilograms of DM times 2 results in 36 kilograms of milk).
- Dividing the kilograms of Holstein milk (3.5 percent milk fat) by the kilograms of dry matter reflects efficiency of converting dry matter to milk. A value greater than 1.5 (for example 36 kg of milk divided by 24 is 1.5) is excellent. A value below 1.3 should be evaluated (milk yield is low or cows are eating too much or both). Factors to review include forage quality, days in milk, age of cows, weigh back adjustment, body weight changes, ration digestibility, and rumen environment.

- If a feeding change occurs and dry matter intake increases by one kilogram or more, continue the change. Increasing feeding frequency, adding a bunk stabilizer (propionic acid-base product), adding buffer, or shifting forage sources are examples that could increase dry matter intake.
- Monitor feed weigh backs targeting 2 to 4 percent of the total fed to a group of cows. Using the Penn State Particle box, shake the orts and determine if orts are within five percent of the original TMR.

■ Economic Comparisons of Feeding Programs

A key measure when evaluating feeding changes is the impact on profitability. Several measurements are listed below for consideration (Hutjens, 2001). Each value can have advantages and disadvantages.

Feed Cost per Cow per Day

Feed cost per cow per day does not reflect milk yield, stage of lactation, or nutrient requirements. A target value in Illinois is less than US $3.50 per cow per day for Holstein cows at 32 kilograms of milk. A better application of this value is divide the components to determine if your costs are optimal for your herd's production and local feed costs (Table 5).

Table 5. Illinois feed costs for a group of cows averaging 32 kilograms of milk (Hutjens, 2001).

Feed	D.M. intake (kg/day)	Cost/kg DM (US$)	Total cost (US$/day)
Forages	11.4	0.09	1.00
Grain energy	6.8	0.11	0.75
Protein supplement	2.2	0.22	0.50
By-product (cottonseed)	1.8	0.18	0.32
Mineral and vitamins	0.45	0.66	0.30
Feed consultant			0.10
Totals	22.7		$2.97

Feed Cost per Kilogram of Dry Matter

Feed cost per kilograms of dry matter is a useful term when comparing similar regions, breeds, and levels of milk production. A target value in Illinois is less than thirteen cents per kilogram of dry matter for Holstein cows at 32 kilograms of milk.

Feed Cost per 100 Pounds (Cwt) of Milk

Feed cost per 100 pounds (cwt) of milk has the advantage of standardizing milk yield allowing for comparisons between groups and farms within a region. Milk yield per cow and feed costs will impact this value. A target value in Illinois is less than $4.50 per cwt for Holstein cows.

Income over Feed Costs (IOFC)

Income over feed costs (IOFC) is a popular value as it provides a benchmark for the herd or groups of cows reflecting profitability, current feed prices, and actual milk prices. If dairy managers have calculated fix costs and other variable costs, IOFC can be used to determine breakeven prices, optimal dry-off time, and culling strategies. A target value in Illinois is over $5.00 ($8.00 Can.) per cow per day.

Marginal Milk Response

Marginal milk response reflects the profit if additional kilograms of milk can be achieved. Generally, this approach is profitable if cows respond to the feeding change because maintenance costs and fixed costs have been covered by previous production. For example, if adding 0.45 kilograms of fat increases milk yield by 1.8 kilograms and fat costs 30 cents (48 cents Can.), then the marginal milk profit is 18 cents (29 cents Can.) if milk is valued at 12 cents (19 cents Can.) per 0.45 kilograms.

Cost Per Unit of Nutrient

Cost per unit of nutrient allows dairy managers to compare the relative cost of a nutrient. If corn is priced at five cents (eight cents Can.) per 0.45 kilograms (dry matter basis), one unit of net energy is worth 5.4 cents (8.6 cents Can.) per Mcal of net energy. If corn is the base energy feed resource, forages, by-product feeds, and other cereal grains can be compared on their cost per unit of nutrient.

Dairy Efficiency

Dairy efficiency can be calculated by expressing the kilograms of milk produced per kilogram of dry matter. Table 6 illustrates a Wisconsin herd summarized by groups. Factors affecting dairy efficiency include group number, days in milk, lactation number, changes in body condition score, growth requirements, milk components, and environmental stress. Dairy efficiency values over 0.6 kilograms for Holstein cows are needed with values over 0.7 optimal. Other nutrients such as percent nitrogen recovery as milk protein or energy captured as milk and tissue can be calculated.

Table 6. Dairy efficiency values for a Wisconsin dairy herd (Hutjens, 2001).

Group	Cow (no)	DIM (days)	Milk (kg)	DMI (lb)	Feed *($US)*	IOFC *($US)*	DE (kg/kg)
1st lact fresh	54	27	19	20	3.06	1.98	0.95
1st lact high	196	124	36	23	3.15	6.33	1.58
1st PG	100	225	29	24	2.67	5.01	1.21
2nd+ fresh	59	20	27	24	3.63	3.57	1.15
2nd + lact high	215	80	46	26	3.65	8.47	1.74
2nd +lact PG	220	276	30	23	2.85	5.19	1.31

References

Anonymous. (2000) Breed averages for dairy cattle. Hoard's Dairyman Magazine. Aug 25.

Hutjens, M.F. (2001) Benchmarking Feeding Programs. Large Herd Management Conference Proc. Las Vegas, NV

Hutjens, M.F. (2001) Evaluating carbohydrate balance in the ration. Four State Dairy Management Proc. MWPS 9. Des Moine, IA. p. 48.

Jordan, E. R., and R.H. Fourdraine. (1993) Characterization of the management practices of the top milk producing herds in the country. J. Dairy Sci. 76:3247.

Oetzel, G.E. (2000) Monitoring blood parameters. AABP Seminar 8 Conference Proc. Rapid City, SD.

Taysom, D. 2000. Personnel communication