# Economics of Making Nutritional Decisions with Volatile Feed Prices

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## INTRODUCTION

Historically, attractive corn prices coupled with its wide availability have led to heavy corn utilization as the main source of energy in dairy feeding programs in the United States. In practical dairy nutrition, this has resulted in corn grain being used to maximize levels and amounts of fermentable carbohydrate that provides energy to both the rumen microbes and to the dairy cow. As a consequence, recent approaches in balancing dairy rations have focused on the optimal level of dietary starch to optimize rumen fermentation and lactation performance (Emanuele, 2005; Grant, 2005).

With the advent of higher corn prices and concurrent price increases in other grains and many by-products, questions have been raised regarding corn use in dairy diets, and alternative feeding and ration balancing strategies with better economic outcomes. The economic need forces the necessity to re-evaluate the role and value of carbohydrates in dairy rations, as well as ration formulation strategies to reduce feed costs. In this paper, we analyze the need for corn in dairy diets; challenge the dogma of a narrow optimal range for dietary starch and non-fiber carbohydrates (**NFC**) in dairy rations, compare current feed and production economics to those that prevailed a few years ago, and explain how maximum economic feed efficiency can be attained.

## COWS DO NOT REQUIRE CORN

Some have mistakenly equated the wide use of corn in dairy rations to a requirement for corn by the animals. This is incorrect both nutritionally and economically. Table 1 summarizes the results of 2 experiments where barley was substituted for corn in lactating cow rations. None of the production, composition, intake, and feed efficiency parameters were significantly affected by the type of grain used. Although some small numerical differences would seem to favor corn, it is important to remember that these studies were designed to maximize production differences between diets. For example, in the experiment of Bilodeau et al. (1989) the substitution was entirely on an ingredient basis. That is, 43.7 % of the diet was either corn or barley without any other dietary adjustments to make the diets isocaloric. Thus, the barley diet had only 97 % of the caloric density of the corn diet.

## LITTLE EVIDENCE FOR NARROW OPTIMUM LEVELS OF STARCH AND NFC

Many nutritional rules of thumbs were derived during times when corn was a very inexpensive feed ingredient. Some of these rules led to good working rations that were economically efficient when corn was cheap. For example, some have recommended constraining dairy diets to 25 to 30 % starch and 35 to 40 % NFC. The

**Table 1.** Effects of feeding corn or barley on milk production, composition, dry matter intake, and feed efficiency.

| | DePeters and Taylor, 1985 | | | Bilodeau et al., 1989 | | |
|---|---|---|---|---|---|---|
| | Corn | Barley | *P* | Corn | Barley | *P* |
| Yield (kg/d) | | | | | | |
| Milk | 28.0 | 27.4 | n.s. | 29.2 | 28.9 | n.s. |
| Fat | 0.835 | 0.761 | n.s. | - | - | n.s. |
| Protein | 0.893 | 0.884 | n.s. | - | - | n.s. |
| Composition (%) | | | | | | |
| Fat | 3.01 | 2.81 | n.s. | 3.98 | 3.96 | n.s. |
| Protein | 3.21 | 3.23 | n.s. | 3.36 | 3.34 | n.s. |
| Dry matter intake (kg/d) | 18.5 | 18.3 | n.s. | | | n.s. |
| Gross feed efficiency | 1.51 | 1.50 | - | 1.33 | 1.31 | - |

experimental evidence to substantiate these recommendations is very thin. What has been lost is that rumen microbes do not have a requirement for starch per se; the energy requirement can be satisfied by fermentable carbohydrate derived from the hydrolysis of either NFC or neutral detergent fiber (**NDF**). Thus, significant amounts of by-product feeds can be used as replacements for corn without much effect on animal productivity.

By-product feeds can be used to replace both forages and grain in dairy cattle diets. Several research articles have been published on the ability of by-products such as corn gluten feed, beet pulp, and soy hulls to replace forage (Boddugari et al., 2001; Clark and Armentano, 1997; Ipharraguerre & Clark, 2003). Alternatively, and more importantly in this era of ethanol euphoria, by-products can also be used to replace grains (Beckman and Weiss, 2005; Boddugari et al., 2000; Ipharraguerre et al., 2002; Voelker & Allen, 2003a). By-products are generally much lower in starch than grains; but contain significant quantities of other NFC, including sugars, organic acids, fructans, glucans, and pectins. These sources of NFC are generally very degradable in the rumen and can provide energy to both the rumen microbes and to the cow. Several research studies have shown no decrease in rumen microbial flow to the small intestine, total tract NFC and NDF digestibilities, dry matter intake (**DMI**), and milk yield and milk components when by-product feeds are substituted for corn grain in dairy rations (Table 2). Starch contents of the diets ranged from 9.2 to 38.3 % DM, with corresponding NFC levels ranging from 27.2 to 50.7 % of DM and NDF levels inversely ranging from 49.4 to 24.3 % of DM. In all of these studies forage NDF levels were maintained within or above current NRC recommendations for forage NDF.

A quadratic response function of milk yield to dietary starch was fitted for each study reported in Table 2. The point of maximum production was estimated by equating the first derivative of this function to 0 and solving for starch. Maximum milk production was achieved at starch levels of 24.4, 33.3, 28.0, and 40.7 % of DM for each of the 4 studies. Clearly, this is a very wide range of optima. In addition, the response functions of milk to dietary starch are very flat, indicating that milk production does not respond very much to dietary starch over a range of 15 to 40 % of DM. The recommended 25 to 30 % range for dietary starch may have resulted in good working rations in the past, but the economic penalty for this myopic view is now, as we shall see, excessive.

**Table 2.** Summary of selected published research demonstrating that replacement of corn grain in lactating cow diets with other sources of fermentable carbohydrate does not impact milk production and can increase feed efficiency. Nutrients are reported on a DM basis. Abbreviations used: WCGF-wet corn gluten feed, SBM-soybean meal, SH-soy hulls, CSH-cottonseed hulls, and HMC-high moisture corn.

| Reference | Diet as described in reference | Forage NDF | Total NDF | NFC | Starch | Milk yield (lb) | DMI (lb) |
|---|---|---|---|---|---|---|---|
| Boddugari et al., 2001 | 0 | 22.8 | 28.2 | 43.2 | 30.3 | 66.9 | 54.3 |
| WCGF vs. corn + SBM | 50 | 22.8 | 35.4 | 36.5 | 23.3 | 67.1 | 49.5 |
| (% WCGF) | 75 | 22.8 | 38.2 | 32.9 | 18.9 | 67.8 | 50.8 |
| | 100 | 22.8 | 41.6 | 29.4 | 15.1 | 64.9 | 48.0 |
| | | | | | | | |
| Beckman & Weiss, 2005 | 35 | 18.2 | 24.7 | 48.3 | 33.3 | 71.1 | 44.7 |
| SH+CSH vs. corn | 29 | 18.2 | 28.6 | 43.7 | 30.1 | 69.7 | 46.2 |
| (% corn) | 23 | 18.2 | 32.2 | 40.4 | 25.4 | 69.5 | 47.7 |
| | | | | | | | |
| Ipharraguerre et al., | | | | | | | |
| 2002 | 0 | 19.1 | 29.4 | 50.7 | 38.3 | 64.9 | 52.4 |
| SH vs. corn | 10 | 19.1 | 34.4 | 44.8 | 31.1 | 64.5 | 54.6 |
| (% SH) | 20 | 19.1 | 39.9 | 39.0 | 23.8 | 65.8 | 53.7 |
| | 30 | 19.1 | 44.8 | 33.1 | 16.5 | 64.5 | 50.4 |
| | 40 | 19.1 | 49.4 | 27.2 | 9.2 | 62.3 | 49.9 |
| | | | | | | | |
| Voelker & Allen, 2003a | 0 | 17.1 | 24.3 | 47.0 | 34.6 | 80.1 | 54.6 |
| beet pulp vs. HMC | 6 | 17.1 | 26.2 | 45.0 | 30.5 | 80.5 | 55.0 |
| (% beet pulp) | 12 | 17.1 | 28.0 | 43.0 | 26.5 | 79.0 | 55.2 |
| | 24 | 17.1 | 31.6 | 39.1 | 18.4 | 77.9 | 50.4 |

A similar method was used to estimate the optimum NFC level in each of the 4 studies listed in Table 2. Maximum milk production was achieved at NFC levels of 37.9, 33.3, 42.4, and 49.7 % of DM across the 4 studies. As for dietary starch, it appears that the optimal NFC level for milk production is poorly defined, and that milk production is not very responsive to NFC level in the diet. Again, a recommendation of 35 to 40 % NFC in dairy rations may have resulted in good, practical rations in the era of cheap feedstuffs, but constraining diets within this narrow range is likely no longer economically optimal.

## WHY DAIRY COWS EXPRESS A SMALL RESPONSE TO STARCH

Significant attention has been given to rumen degradation rates of dietary carbohydrate fractions and synchronization of rumen degradable protein with carbohydrates. This has culminated in an emphasis on these rates in static nutrition models currently used in the field. Static models estimate nutrient availability at a single time point; they do not integrate over time as dynamic models do.

While the carbohydrates in NFC (sugars, organic acids, fructans, glucans, pectins, and starch) and in NDF (hemicellulose and cellulose) have different degradation rates from each other which can vary under different conditions; the degradation products of all of these supply a single rumen carbohydrate pool that is potentially fermentable by microbes, designated as the fermentable carbohydrate (**FC**) pool here. Because cows eat multiple meals/d and there are multiple carbohydrate fractions that contribute to the FC pool, this pool approaches steady-state kinetics under common dairy management practices (Figure 1A). Altering the proportion of starch vs. other carbohydrates does not change the flow into the FC pool (Diet A vs. Diet B). The FC pool is rapidly fermented by the rumen microbes, providing energy for their maintenance and growth, and VFA to the cow for energy and milk precursors. Consequently, varying dietary starch content does not change the energy availability to the microbes or the cow, given that total NFC is maintained and that the carbohydrate fractions are degradable. This conclusion is supported by experimental evidence that demonstrates no change in microbial protein flow to the small intestine when dietary starch content is varied (Voelker and Allen, 2003b; Ipharraguerre et al., 2005).

This lack of difference between diets with altered NFC components also holds true under non-steady-state conditions (Figure 1B), such as slug feeding during heat stress situations. The pool of each carbohydrate will vary over the course of the day as a function of meal size and meal intervals, but as long as the total NFC and NDF levels are maintained, there is no difference in replacing starch with other NFC. The model assumes that passage of the carbohydrate fractions out of the rumen is not affected by the meal feeding pattern. Note that during the 12-hr period when the cow is eating, the FC pool approaches steady-state (19 hr to 7 hr). Replacing the starch in corn grain with equal amounts of other NFC or digestible NDF in by-product feedstuffs does not change energy availability, despite differences in rumen degradation rates between carbohydrate fractions.

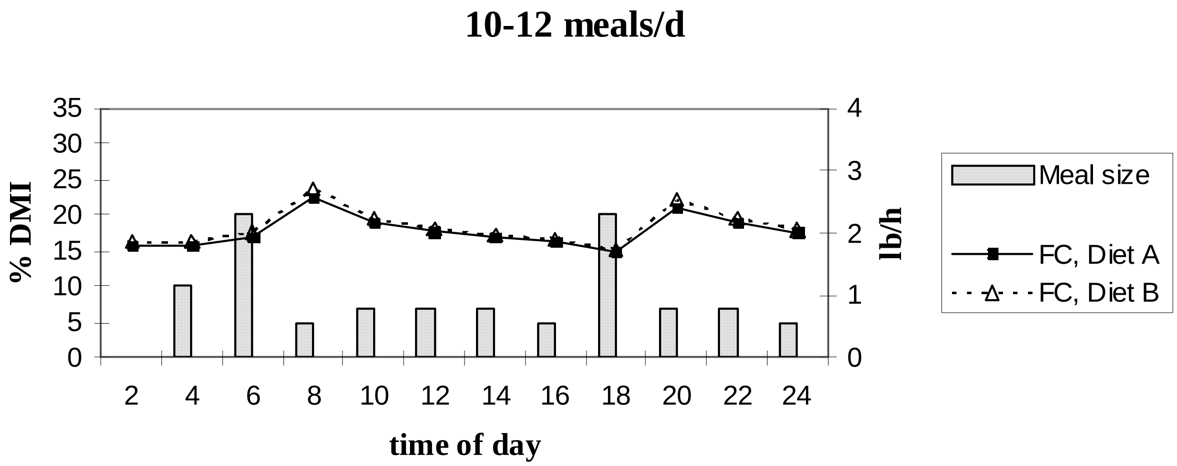
## COMPARING AND EVALUATING FEEDSTUFFS

A simple approach to evaluating feedstuffs is to compare their cost/unit of energy and protein. Energy can be based on total digestible nutrients (**TDN**) or net energy for lactation (**$NE_L$**). Traditionally, prices/unit of energy and crude protein (**CP**) were based on the cost of corn and soybean meal, respectively. This approach, first proposed by Petersen (1932) and found in most applied nutrition books, such as that of Morrison (1956), assumes that these 2 feeds are perfectly priced. That is, the assumption here is that their selling prices are always equal to the economic value of their nutrients. This assumption doesn't make much economic sense as it would imply perfect and efficient markets. That this doesn't hold has been very evident with the current erratic grain and protein prices. The simple energy/protein approach also ignores other nutrients that are important in ruminant nutrition.

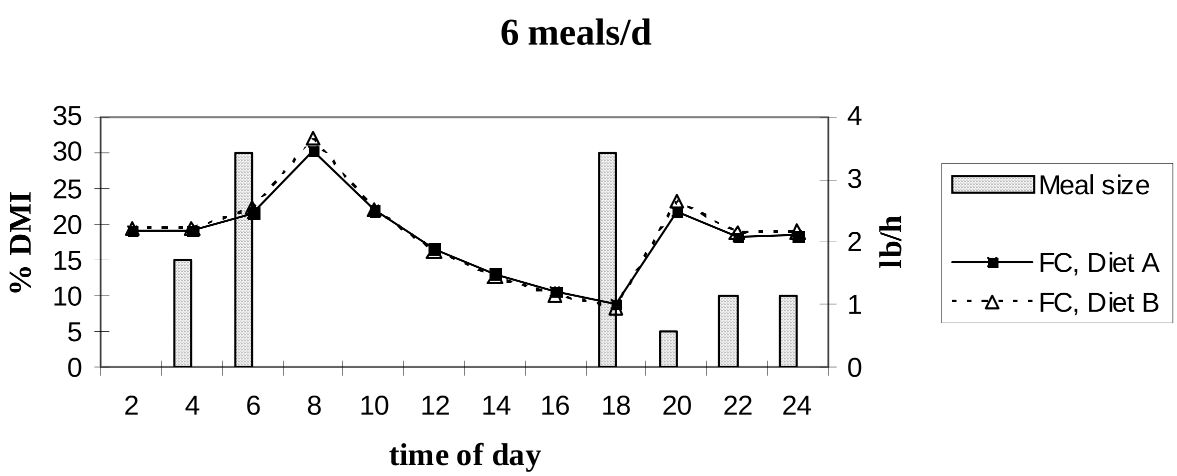
Additional approaches have been developed to include consideration of multiple nutrients. Increasing nutritional costs are captured in FEEDVAL (Howard & Shaver, 1997), which evaluates feedstuffs based on CP, TDN, calcium, and phosphorus

**Figure 1.** Energy availability to rumen microbes is not altered by varying starch content while maintaining NFC with other sources of fermentable carbohydrate (**FC**) under either semi-steady state (10-12 meals/d, panel A) or non-steady state (6 meals/d, panel B) feeding conditions. Diet A contains 30 % NDF, 40 % NFC, 25 % starch, and Diet B contains 30 % NDF, 40 % NFC, 15 % starch.

**A**




**B**




using 4 reference feedstuffs. Earlier versions have also allowed evaluations based on RUP. Because the reference feedstuff for energy is shelled corn, the value of energy predicted by this program will be high when corn prices are high. Fundamentally, the approach is nothing more than an expansion of the Petersen method for more than 2 nutrients and, thus, suffers the same limitations as the Petersen method.

A method that uses prices and nutritional composition from all feedstuffs traded in a given market has been proposed by St-Pierre and Glamocic (2000). The method uses a multiple regression approach to set as many equations as there are feedstuffs. Estimates of unit costs for each important nutrient are obtained by least-squares. The resulting software, ***Sesame III*** is a Windows-based program and is available at www.sesamesoft.com. This program uses a multiple regression approach to estimate break-even prices of a set of feedstuffs based on their nutrient contents and market prices. Consequently, it can be used to determine the relative price of individual feedstuffs within a defined market area. The cost of a unit of a given nutrient, e.g., $NE_L$ or RUP, is also estimated.

Using this method, we can compare the nutrient costs prevailing in 2004 when grains and protein prices were relatively in equilibrium to those prevailing during January 2008 after the onset of the corn ethanol euphoria (Table 3). Costs reported here are for central Ohio, where the authors have access to accurate feed markets information. These costs, as well as feed availability, would be different in the High Plains feed markets; but the analysis would be identical, yielding similar results. The cost per Mcal of $NE_L$ in the eastern Midwest has increased by nearly 60 % during the 3-yr period, going from $0.087 to nearly $0.136/Mcal. To put this substantial increase in an even better perspective, unit cost of $NE_L$ averaged $0.07/Mcal during the 15-yr period that extended from 1982 to 1997 and never even exceeded $0.10/Mcal during this same 15-yr period (St-Pierre and Thraen, 1999). Thus, the current price for dietary energy resides in a completely unchartered territory. Meanwhile, the cost/unit of rumen degradable protein (**RDP**) dropped by $0.12/lb between summer 2004 and winter 2008. During that same period, digestible rumen undegradable protein (**d-RUP**), non-effective NDF (**ne-NDF**), and effective NDF (**e-NDF**) unit costs increased by $0.04, $0.02, and $0.07/lb respectively. Thus, although the price of soybean meal appears to be high from a historical perspective, this doesn't imply that the prices of protein fractions (RDP and d-RUP) are also high. In fact, once we account for the increased economic value of the dietary energy contained in the protein feeds, many of them, such as expeller soybean meal are currently under-priced (Table 4). The comparison of the economic value of different commodities being traded in the Midwest yields some interesting and even surprising results. Most people would think that $4.65/bu corn implies that corn is relatively expensive. It may be so from a historical standpoint, but corn is currently a bargain feed compared to all other commodities (Table 4). What is easily overlooked is the drastic rise in the price of many other *energy* feeds in the last 3 yr, such as tallow which is now trading at nearly twice its 2004 price. During this period, however, some feeds, mostly corn

**Table 3.** Estimates of nutrient unit costs, central Ohio, for July 2004 and January 2008.

| Nutrients | July 2004 | January 2008 |
|---|---|---|
| | ------------------ $/unit[1] | -------------------- |
| Net energy lactation | $ 0.087 | $ 0.136 |
| Rumen degradable protein | $ 0.023 | $ -0.093 |
| Digestible-rumen undegradable protein | $ 0.342 | $ 0.383 |
| Non-effective NDF | $ -0.058 | $ -0.037 |
| Effective NDF | $ 0.054 | $0.121 |

[1] Units are Mcal for $NE_L$, and lb for all other nutrients.

by-product feeds, have remained or have become extremely well priced.

## MAKING BETTER USE OF BY-PRODUCT FEEDS

Strategically, one should benefit from maximizing the use of feeds deemed bargains in our prior analysis. As an example of how this can be accomplished, we balanced a ration for a 1400 lb cow producing 80 lb of milk/d at 3.7 % fat and 3.0 % protein using prices that prevailed in central Ohio during summer 2004. In doing so, we did not use a least-cost programming algorithm, but used ingredients that have traditionally formed the basis of a traditional Midwestern diet (Table 5). Using the information from Table 4, we modified the selection of ingredients to reflect the market conditions in January 2008. In doing so, we reduced the amount of corn fed by 25 % and whole cottonseed by 50 %, eliminated wet brewers grains, 44 % solvent extracted

**Table 4.** Actual and break-even feed prices for Central Ohio, July 2004 vs. January 2008, using Sesame III. Break-even prices were based on net energy lactation ($NE_L$), rumen degradable protein (RDP), digestible rumen undegradable protein (d-RUP), effective NDF (e-NDF), and non-effective NDF (ne-NDF).

| | 2004 | | 2008 | |
|---|---|---|---|---|
| Feedstuffs | Actual | Break-even | Actual | Break-even |
| | ---------------------------- | $/ton | ---------------------------- | |
| Alfalfa hay, 44 % NDF, 20 % CP | 130 | 150 | 180 | 209 |
| Bakery by-product meal | 127 | 154 | 210 | 225 |
| Beet pulp, dried | 160 | 122 | 290 | 210 |
| Blood meal, ring dried | 600 | 540 | 670 | 632 |
| Brewers grains, wet | 35 | 36 | 35 | 51 |
| Canola meal | 189 | 181 | 294 | 224 |
| Citrus pulp, dried | 126 | 122 | 236 | 196 |
| Corn grain, ground | 110 | 156 | 177 | 231 |
| Corn silage, 35 % DM | 40 | 53 | 55 | 88 |
| Cottonseed, whole w lint | 208 | 221 | 319 | 325 |
| Distillers dried grains w solubles | 156 | 184 | 176 | 257 |
| Feathers, hydrolyzed meal | 330 | 422 | 385 | 472 |
| Gluten feed, dry | 102 | 155 | 177 | 217 |
| Gluten meal, dry | 369 | 430 | 559 | 526 |
| Hominy | 132 | 137 | 155 | 206 |
| Meat meal | 280 | 317 | 355 | 360 |
| Molasses | 105 | 107 | 160 | 155 |
| Soybean hulls | 112 | 74 | 178 | 143 |
| Soybean meal, expeller | 380 | 344 | 405 | 443 |
| Soybean meal, solvent 44 % | 336 | 253 | 366 | 290 |
| Soybean meal, solvent 48 % | 345 | 294 | 375 | 338 |
| Soybean seeds, roasted | 380 | 318 | 448 | 410 |
| Tallow | 370 | 358 | 570 | 558 |
| Wheat bran | 79 | 93 | 152 | 146 |
| Wheat middlings | 71 | 112 | 145 | 166 |

soybean meal, and tallow, and incorporated some distillers dried grains with solubles, corn hominy, corn gluten feed, and wheat middlings (Table 5, 2008). The resulting diet is nutritionally nearly identical to the traditional Midwest dairy diet. Its cost, however, is $0.25/cow/d less, resulting in estimated savings in feed costs of more than $80/lactation. Although by-products are nutritionally much more variables than grains and oilseed meals (NRC, 2001), their contribution to the nutritional variance of the whole diet is approximately proportional to the square of their inclusion rates (St-Pierre and Harvey, 1986). Because the '2008' diet uses relatively small amounts of each of the by-products, the resulting diet in fact has a lower expected nutritional variance for all major nutrients than the traditional diet (St-Pierre and Weiss, 2006).

**Table 5.** Comparison of a dairy diet optimized for prevailing feed prices in summer 2004 vs. January 2008.[a, b]

| **Ingredients** | **2004** | **2008** |
|---|---|---|
| | ------- lb as fed/d ------- | |
| Legume hay | 4.2 | 4.2 |
| Legume silage | 19.5 | 19.5 |
| Corn silage | 37.0 | 37.0 |
| Wet brewers grains | 13.8 | 0.0 |
| Cottonseed, whole | 5.0 | 2.75 |
| Corn grain | 15.0 | 11.25 |
| Soybean meal, solvent, 44 % | 2.25 | 0.0 |
| Soybean meal, expeller | 2.25 | 2.75 |
| Dried distillers grains with solubles | 0.0 | 3.33 |
| Hominy | 0.0 | 2.25 |
| Corn gluten feed | 0.0 | 2.75 |
| Wheat middlings | 0.0 | 2.75 |
| Tallow | 0.5 | 0.0 |
| Minerals and vitamins | 1.5 | 1.5 |
| | | |
| **Composition** | | |
| Dry matter (lb) | 51.3 | 51.3 |
| $NE_L$ (Mcal/lb) | 0.74 | 0.73 |
| | -------- % of DM -------- | |
| CP | 17.0 | 16.7 |
| RDP | 11.3 | 10.8 |
| RUP | 5.6 | 5.8 |
| MP | 10.6 | 10.6 |
| NDF | 32.2 | 33.3 |
| NFC | 42.5 | 42.8 |
| Ether extracts | 5.7 | 4.6 |
| **Cost in January 2008 ($/cow/d)**[b] | 4.75 | 4.50 |

[a] Rations balanced for a 1400 lb cow producing 80 lb of milk/d at 3.7 % fat and 3.0 % true protein.
[b] Prices used are those reported in Table 4 for central Ohio in January 2008.

## FEEDING STRATEGIES TO OPTIMIZE PROFITS WITH HIGH FEED PRICES

Other strategies to profit optimization will be briefly discussed: 1) altering nutrient specification of diets based on feeds and milk prices, 2) increasing forage inclusion, and 3) increasing forage quality. These 3 approaches may be best used in combination.

Dairy producers should always target less than maximum milk yield in order to optimize income over feed costs and profits (St-Pierre, 1998). When milk price is relatively high and feed costs are relatively low, such as in the late 1990's, the optimum nutritional levels (i.e., nutrient concentrations in the diet) are very near those required for maximum milk production. But when milk price is low or feed prices are high, the optimal levels can be significantly less than those required to support maximum milk production. The exact mathematical optimization requires a known response function to nutritional inputs. Work has been done in this area (Bath and Bennett, 1980; St-Pierre and Thraen, 1999) but the suggested approaches lack the required precision to make them useful in practice. For the time being, different strategies can be evaluated using available ration balancing software (NRC, CPM Dairy, CNCPS, etc.) and the expert help of a professional nutritionist. Generally, forages are a cost-effective way to deliver nutrients to ruminants. Increasing inclusion of forages in place of concentrates can affect NDF, CP, RUP, NFC, and $NE_L$ levels in a ration as well as increasing forage NDF and physically effective NDF (**peNDF**). Significant attention has been given to minimum levels of forage NDF or peNDF to ensure adequate rumination and prevent rumen acidosis and milk fat depression (Shaver, 2000; Mertens, 1994). Maximum NDF levels are determined by $NE_L$ requirements (NRC, 2001; Mertens, 1994), and are affected by NDF digestibility.

Over the past 18 months in Ohio, corn silage, and alfalfa silage have been at break-even or lower-than-predicted values as determined using Sesame III. However, many Ohio dairy producers were not maximizing forage in rations until recently, with forages included only at 40 to 45 % of DMI. As grain prices have increased since the 2006 harvest, significant increases in forage utilization have occurred, often with little or no decrease in milk yield.

Better quality forages can be utilized more extensively in dairy rations than poorer ones. Quality is defined as the ability of the forage to deliver digestible nutrients (energy, protein, etc.) to the cow. While *in vitro* and *in situ* NDF digestibility assays are available, the poor correlation between these measures and *in vivo* NDF digestibility limits their value in predicting energy availability and lactation performance. Maturity and DM content at harvest have large impacts on forage quality, as do harvesting and storage procedures. Grain content of the small grain silages and corn silage also has a large impact on forage quality and the potential to increase forage proportions in a ration (Table 6) as well as the economic return from milk production.

## TAKE-HOME MESSAGE

Many dairy producers have reduced corn inclusion in rations for lactating dairy cows by 25 to 35 % by increasing forage and by-product utilization without sacrificing milk yield or milk components. The keys to success are:

**Table 6.** NDF digestibility and starch content of corn silage is important in determining feeding value.[a]

| Quality | Moisture (%) | NDF (%) | CWD[b] (%) | Starch (%) | Net Energy Lactation (Mcal/lb) | Partial Milk, (lb/cow)[c] | Partial Milk Income ($/cow)[d] | IOFC per 1000 cows ($/d)[e] |
|---|---|---|---|---|---|---|---|---|
| Poor | 69.3 | 53.5 | 42.4 | 15.5 | .453 | 13.1 | $2.62 | $1870 |
| Fair | 69.1 | 46.4 | 48.0 | 25.5 | .526 | 15.3 | $3.06 | $2310 |
| Medium | 67.3 | 41.9 | 51.0 | 30.9 | .561 | 17.3 | $3.46 | $2710 |
| Good | 63.3 | 39.7 | 53.8 | 35.2 | .590 | 20.4 | $4.08 | $3330 |
| Average | 68.7 | 45.4 | 48.7 | 26.7 | .533 | 15.7 | $3.14 | $2390 |

[a] Data on more than 700 samples from California kindly provided by Agri-King, Inc.
[b] CWD = Cell wall (NDF) digestibility.
[c] Predicted milk yield (lb/cow/d) from 30 lb of corn silage based on forage energy content and milk fat at 3.5 %.
[d] Milk income ($/cow/d) with milk price at $20.00/cwt.
[e] IOFC = Partial daily income over feed cost/1000 cows with corn silage priced at $50/T.

1. Maximize forage quality and optimize forage allocation.
2. Periodically question the need of every feed ingredient in your dairy rations. Cows do not have requirements for feeds (i.e., corn) but for nutrients.
3. Question narrow nutrient constraints when formulating dairy rations. Many such constraints are not well supported by *in vivo* data (i.e., cows can do quite well with diets that do not contain 25 % starch).
4. Alter diet specifications based on price of milk and feed inputs.
5. Maximize the use of bargain feedstuffs; minimize the use of over-priced feedstuffs.

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