RATION FORMULATION: SOME RISK/BENEFIT DECISIONS TO THINK ABOUT

H. H. (Jack) Van Horn
Department of Dairy and Poultry Sciences
University of Florida, IFAS
Gainesville 32611-0920

More than ever, in tough financial times, dairymen are wanting to cut costs to the bone. With feed representing the largest single cost of producing milk, feed is a logical place to look for savings, that is savings that will not reduce production appreciably and will result in an increase in income over feed costs. The purpose of this paper and related comments by nutritional consultants in accompanying comments in this proceedings is to review some ration formulation practices, a few key ingredients, and management strategies that can help to increase income over feed costs in the short run without creating undue risks in the long run. Some things to consider are:

1. Do everything you can to maximize dry matter intake.
2. Feed high concentrate diets in today's feed market; even with grazing programs it will be profitable to feed good cows more than 20 lb concentrate per day.
3. Don't undervalue cottonseed hulls; the main value appears when they are included at 10 to 15% of diet dry matter.
4. Don't overvalue alfalfa.
5. Don't expect too much out of bypass protein.
6. Expect only 2 to 3 lb of extra milk per day from supplemental fat.
7. Don't overvalue whole cottonseed.
8. Don't overfeed phosphorus.
9. Scrutinize other additives.

Maximize Dry Matter Intake (DMI)

The last place to economize is in the amount that you feed of the economical ration that you select. Invariably, extra DMI will give more milk, at least 1 lb of milk for 1 lb of DM for cows in mid-lactation being fed high energy diets and considerably more from cows in early lactation. In a summary of 20 experiments with 1688 measures of milk yield responses to DMI in Holstein cows being fed different diets, there were linear responses to increasing DMI and net energy intake (Figure 1). On average these cows were in mid-lactation and cows in several experiments were fed relatively low energy diets. Overall, milk yield increased .95 lb for ever extra pound of DMI. For application, it is better to use the response to estimated energy intake even though DMI and net energy intake are perfectly related for a particular diet formulation. Net energy intake lets us expect more milk from a pound of DMI from a high-energy diet than from a low-energy diet. In this data set, 1 lb of milk was returned for each extra .68 megacalories (Mcal) of estimated net energy of lactation (NEL). Thus, if a diet formulation provided .75 Mcal NEL per lb of DM, a probable average for confined Florida dairies, you would expect .75/.68 or 1.1 lb more milk.

Presented at the 32nd Florida Dairy Production Conference, Gainesville, April 11-12, 1995

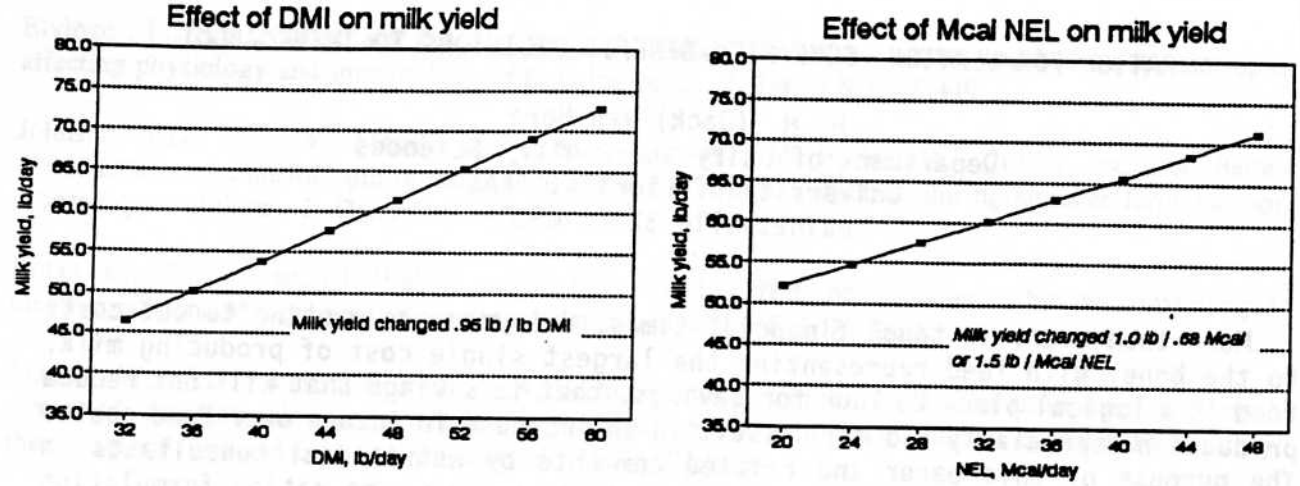

Figure 1. Linear effects of dry matter intake (DMI) and intake of net energy for lactation (NEL) on milk yield in mid-lactation cows. From Briceno et al. (1987).

The main point is that a pound of dry matter probably costs between 6 and 7 cents currently and milk returns at least 13 cents/lb or a total of at least 14 cents if that dry matter contains .75 Mcal and returned 1.1 lb of milk to the dairyman. Early lactation cows will give an even higher return (probably about 1.5 to 2.0 lb milk) from each extra pound that managers can get fresh cows to eat and the benefit will carry over into later lactation. Additionally, the extra energy consumption will be beneficial to improved reproduction.

How do you get more DMI? It will depend on doing a lot of little things well. Some points are: 1) adequate bunk space; 2) fresh feed, fresh silage is particularly important because of heating from secondary fermentation started at the silo due to poor management in loading; 3) clean bunks; 4) work with feeders to let them know how important feed bunk management is to cow performance; and 5) know how much cows are eating and, if intake already is high, don't raise it too much just because there isn't a lot of refusal in the bunks. A large increase today may lead to overeating today and, hence, refusals and cleanup duties tomorrow. Make increases gradually.

Increasing DMI in cows in grazing dairies will pay off at least as well as in confined dairies, maybe better. Thus, management practices to provide higher quality forages, grazing opportunity during the cooler parts of the day, and maximum concentrate intake at milking time will give returns at least as good as those in confinement dairies.

Feed High Concentrate Diets

If energy and protein, the major costs rations, are cheaper from concentrates than forages, the question becomes how far can one go in substituting concentrate ingredients for roughages. Ruminants require a minimum amount of roughage to maintain rumen health, to avoid excessive depression of milk fat percentage, and to avoid other problems that come with excessive acid production associated with high concentrate feeding, for example, laminitis. However, within the range from all-forage diets to diets described as minimum roughage (roughage less than 30% of total diet DM), substituting concentrates for forages usually increases DM intake slightly, energy intake appreciably, milk yield appreciably, milk protein percentage slightly, and depresses milk fat percentage slightly. Most Florida dairymen feed minimum roughage diets or close to that because a combination of feed grains and byproducts usually have been more economical sources of nutrients than forages. Cow health is maintained more easily if minimum roughage rations are fed as total mixed rations (TMRs) rather than when ingredients are fed separately. With minimum roughage, the major priority is to get cows to consume minimum effective fiber in order to avoid excessive rumen acidosis.

With today's cheap concentrates, it is doubtful if even those dairymen utilizing intensive grazing can produce energy and protein from pasture as cheaply as they can purchase them from concentrates. This suggests that the real competitive advantage of intensive grazing is in reducing capital costs associated with buildings and equipment and in reducing cow replacement costs through better foot health, fewer displaced abomasums, etc.

Don't Undervalue Cottonseed Hulls

Cottonseed hulls (CSH) have an average composition (book value, NRC, 1989, dry matter basis) of .45 Mcal NE_L/lb dry matter (DM), 4.1% crude protein (CP), 73% ADF, and 90% NDF. These values suggest very low quality when compared to corn silage (.73 Mcal NE_L/lb DM, 8.1% CP, 28% ADF and 51% NDF) or high quality alfalfa grass hays that may be as high as .68 Mcal NE_L/lb DM, ADF% <30%, and NDF% 40 to 70% (depending on source). However, research and experience indicate CSH are unique and may have a place in diets for high producing cows in spite of their low energy per lb (NE_L). Their uniqueness probably is due to CSH being a combination of a highly digestible cellulose (cotton fibers) and a nearly indigestible hull that is dense enough to pass rapidly through the digestive tract after the cotton fibers are digested.

Cows eating diets containing CSH consistently eat more DM and produce slightly greater amounts of milk than diets based on corn silage or other forages. Thus, the important question is when can you obtain greater profits using CSH in dairy diets. Or perhaps, at what relative costs of CSH to other ingredients do CSH figure profitably in dairy cow diets.

Value of Cottonseed Hulls at >30% of Ration Compared with Corn Silage and Alfalfa. Harris et al. (1984) conducted four experiments in which CSH-based total mixed rations (TMR) were compared to corn silage-based TMR. Holstein cows eating CSH diets produced greater milk yields (58.1 lb milk/day versus 53.7 lb/day with corn silage). The major reason was greater DM intake (53.7 lb/day versus 43.8 lb/day with corn silage-based diets). In these experiments, the CSH diets supplied all of the roughage needs; the diets contained an average of 36.2% CSH. The corn silage-based diets averaged 39.7% corn silage (DM basis). Milk fat percentages averaged slightly higher with CSH (3.44% versus 3.25% for corn silage) probably because DM consumption and nongrain roughage consumption from

Table 1. Milk Income Minus Feed Costs (MIMFC) for Cows Fed Diets Based on Corn Silage (CS) or Cottonseed Hulls (CSH).[1] Yield data from Harris et al. (1984).		
Measurement	CSH	CS
Milk Yield, lb/d	58.1	53.7
Milk Income, $/d	8.13	7.52
Feed DM Intake, lb/d	53.7	43.8
Feed Costs, $/d	**3.56****	2.95
MIMFC, $/d	4.57	4.57
If CSH cost $64.19/ton as-fed.		

Table 2. MIMFC for Cows Fed Diets based on Alfalfa or CSH.[1] From Morales et al. (1989)	
CSH	Alfalfa
58.1	56.1
7.84	7.80
54.1	51.0
3.67**	3.64
4.16	4.16
If CSH cost $69.91/ton as fed	

[1]Milk price used was $14.00/cwt for 3.5% fat milk with $.07 differential. Milks in Table 1 were considered equal in fat content at 3.5%. In Table 2, milk from cows fed CSH diets averaged 2.77% fat; milk from alfalfa-fed cows 3.38%. Prices for corn, 49% soybean meal, and mineral/vitamin supplement were $112.50, $216.00/ton, and $300/ton, as fed (both tables). Corn silage was fixed at $90/ton DM ($27/ton of 30% DM silage). In Table 2, alfalfa was fixed at $120/ton DM ($108/ton of 90% DM hay).

Table 3. Breakeven costs of Feeding Cottonseed Hulls Compared to Corn Silage at Various Prices for Corn Silage.

Corn Silage		Cottonseed Hulls	
$/wet ton	$/dry ton	$/wet ton	$/dry ton
27	90	64	71
30	100	72	80
36	120	88	98

Table 4. Breakeven Costs of Feeding Cottonseed Hulls Compared to Alfalfa at Various Prices for Alfalfa Hay.

Alfalfa Hay		Cottonseed Hulls	
$/wet ton	$/dry ton	$/wet ton	$/dry ton
108	120	72	80
135	150	102	113
162	180	132	146

corn silage were both lower than with CSH. Table 1 shows data from these four experiments and shows that income over feed costs would have been equalized if CSH cost $64.19/ton. This can be used as a comparative value with 30% DM corn silage at $27/ton when CSH are used to supply all of the roughage needs.

A University of Florida experiment (Morales et.al., 1989) compared TMR based on roughages of either 30% CSH or 35% alfalfa haylage. Cows consuming CSH diets produced 58.1 lb milk/day with 54.1 lb/day DMI and cows fed alfalfa haylage diets produced 56.1 lb/day with 51.0 lb/day DMI. Milk fat percentages were lower with CSH (2.77 versus 3.38% with alfalfa haylage).

Using the same procedure as with corn silage, income over feed costs were equalized with CSH at $69.91/ton as fed (Table 2) which can used as a comparative

Table 5. Comparison of alfalfa hay, bermudagrass hay and cottonseed hulls in corn silage diets.[1]

Ingredients and response	Diet forage base			
	Corn silage	CS + alf. hay	CS + berm. H.	CS + CSH
Corn silage (% DM)	45	33.8	33.8	33.8
Alfalfa hay (% DM)		11.2		
Bermuda hay (% DM)			11.2	
Cottonseed hulls (% DM)				11.2
Concentrate (% DM)	55	55	55	55
DMI	47.3	48.8	46.0	49.8
Milk (SCM)	58.0	58.0	54.4	59.6
Lb milk/lb DM	1.23	1.19	1.18	1.20

[1]From Adams et al. (1995).

value with alfalfa hay at $108/ton as fed, the cost of alfalfa used in this example. for the two diets. For alfalfa diets, formulation (DM basis) used was 35% alfalfa 49.5% corn, 12.5% SBM (49%), and 3% mineral/vitamin supplement giving a 18% CP diet. Higher protein was chosen for alfalfa TMR because past research here has shown that higher protein is needed with alfalfa-based diets (Van Horn et al., 1985), probably because of high ruminal degradability of alfalfa protein. The CSH TMR was formulated at 15.6% CP. In this comparison, milk fat percentage was considered with a differential of $.07/.1% change in milk fat percentage.

Some suggested values of CSH relative to corn silage and alfalfa hay at different prices are shown in Tables 3 and 4.

Marginal Value of CSH When Used at only 10 to 15% of Ration Dry Matter. The value of CSH is greater if smaller quantities stimulate total DMI and milk yield or have positive effects on total diet utilization. For example, other diets in the experiment of Morales et al. (1989) contained either 65% alfalfa haylage or 35% alfalfa haylage plus 14% CSH. These were compared to the 30% CSH and 35% alfalfa haylage diets previously discussed. As one might expect, cows fed 65% alfalfa haylage diets (only 35% concentrate) ate less DM and produced less milk. However, the cows fed 35% alfalfa haylage and 14% CSH ate and produced almost identically as cows fed 35% alfalfa haylage. CSH had been substituted for corn (adjusted slightly with SBM to equalize protein). Thus, in this comparison, CSH DM was equal to corn DM, a much higher energy value than book values suggest.

In another experiment (Table 5), CSH were compared directly with good quality, estern alfalfa hay at 11.2% of the TMR DM and diet crude protein equalized at 7% of DM. Milk production was 1.6 lb/day more with CSH and DMI was only 1.0 ɔ/day more; milk fat percentage was .13 percentage units higher with CSH (3.62 ;. 3.49%). Thus, in this experiment with CSH at 11.2% of diet DM, CSH outperformed alfalfa. Note that diets with 11.2% bermudagrass hay, which had similar estimated energy content as CSH, gave much poorer performance because of lower DMI.

Don't Overvalue Alfalfa

Alfalfa is one of the best forages available to produce milk in the United States. There is no question about that. The point here is to ask if it supplies something more of value than energy and protein and, perhaps, effective fiber that is more productive than other effective fiber sources.

If you decide that alfalfa is just a source of energy and protein and calculate a relative value for it based on what it would cost to buy an equivalent amount of energy and protein from corn ($115/ton as fed, $129.20/ton of DM, DM = dry matter) and soybean meal ($220/ton of 49% CP as fed, $244.40/ton of DM), its value (18% CP hay as fed basis, 20% of DM) is about $114/ton of DM or $103/ton as fed. Dairymen who are feeding alfalfa are paying a lot more than this ($160 to $180/ton as fed). However, does alfalfa offer advantages to the total diet above its replacement value of energy and protein? Also, can alternate roughage sources such as corn silage, sorghum silage, or bermudagrass hay with formulation adjustments be used in place of alfalfa without sacrificing milk production?

Few studies are available which compare alfalfa to other forages at various forage:concentrate ratios. Several experiments have compared alfalfa hay to corn silage when forage supplied about 50% of diet DM and no gain in milk production was obtained when alfalfa replaced corn silage. In one experiment designed to see if higher total dietary protein percentages were needed with alfalfa supplemented diets (Van Horn et al., 1985), we found that alfalfa hay and corn silage provided equal milk yields in diets which were 50% forage (DM basis) when total diet protein was 18% of DM but alfalfa hay was not as good as corn silage in 14% crude protein diets. Another Florida experiment compared corn silage, alfalfa, and perennial peanut as the sole forage sources in diets which were either 70:30 or 30:70 in forage:concentrate ratio. Milk productions were not different between forage sources.

It has been proposed by Mertens (1992) that balancing diets to equal NDF content is a way of adjusting for differences in forage quality. For example, a Canadian study (Beauchemin, 1991) showed that performance was equal when diets based on higher quality alfalfa (early cut) or midbloom alfalfa were balanced for NDF, thus feeding more concentrate with midbloom alfalfa to offset its greater NDF content. Similarly, an Arizona study (Poore et al., 1991) showed that wheat straw substituted effectively for alfalfa hay with regard to milk yield when TMRs were balanced to about 31% NDF. Milk fat percentage declined with added straw such that the effect on FCM was depressed when all of the alfalfa NDF was replaced with straw and concentrate.

Staples et al. (1992) designed a study specifically to evaluate if imported alfalfa hay is worth a premium above its energy and protein value. They substituted 17.5% of diet DM with alfalfa pound for pound for either corn silage, sorghum silage, tropical corn silage, bermudagrass silage, or all of the bermudagrass hay in a diet containing 29% of DM from cottonseed hulls. Base diets for each forage were formulated to 35% NDF except for cottonseed hull diets which were formulated to a higher NDF%. No change in FCM occurred when alfalfa replaced corn silage DM and production actually declined some when alfalfa replaced bermudagrass hay in a cottonseed hull-based diet. Where alfalfa did have greater value than the forage replaced was with sorghum silage, tropical corn silage, and bermudagrass silage but there the gain was largely accounted for by increased DM intake.

Gains in DM intake are important. Value of alfalfa is increased if it stimulates greater intake, particularly in early lactation when achieving higher peak production may extend increased production into later lactation. Based upon the study of Staples et al. (1992), cows producing about 50 lb of milk/day and fed about 8.5 lb/day (as fed) of chopped alfalfa hay in a TMR were less profitable than cows not fed alfalfa hay ($180/ton); greater milk incomes were offset by greater feed costs with alfalfa in the diet. However, the profitability picture for cows fed alfalfa in place of sorghum silage, tropical corn silage or bermudagrass silage during the first 100 days of lactation may be different. An additional 3 to 4 lb of milk/day would be required to offset the expected increased feed costs. But increased peak yields result in an additional 200 lb of total milk yield in a 10-month lactation period. Therefore, benefits from feeding alfalfa hay the first third of the lactation period and then removing it from the diet may extend throughout the entire lactation.

Some conclusions from these studies are:

1. Performance gains are not to be expected when comparing alfalfa against good quality corn silage.

2. There's little doubt that premium quality alfalfa is a superior forage to most other forages; therefore, a pound-for-pound replacement of various roughages with alfalfa hay often will benefit milk production. However when alfalfa replaces other roughages on a pound of NDF-for-pound of NDF basis, animal performances may not differ. Replacement on the basis of NDF results in more concentrate being fed in diets without alfalfa because other forages are higher in NDF than alfalfa. Benefits of feeding alfalfa must overcome concentrates and forage competitors priced below alfalfa and those benefits are primarily increased DM intake.

3. Alfalfa hay may not be worth more than bermudagrass hay in cottonseed hull-based diets due to fast passage of hulls through the digestive tract.

Thus, alfalfa probably is not worth a premium above its calculated relative ılue for energy and protein unless increases in DM intake can be obtained. How ın a dairyman know if alfalfa is giving an extra response in his herd? Changes DM intake are quickly reflected in changes in milk production. Therefore, it usually possible to put alfalfa into the diet for a week, take it out, and put it in again (or vice versa) and see if the change had an effect.

Don't Expect Too Much out of Bypass Protein.

All of the bypass protein supplements such as blood meal, meat and bone meal, feather meal, distillers dried grains, wet brewers grains, corn gluten meal, etc. can be utilized effectively as protein sources for lactating dairy cows. However, responses above soybean meal-supplemented control diets have been small and inconsistent, particularly with corn silage-based or cottonseed hull-based diets. Corn gluten meal appears least likely to be worth more than equivalent value of its protein and energy content purchased in the form of soybean meal and corn.

With alfalfa-based diets and high-protein grazing forages, fish meal and heat-treated soybean products give fairly consistent responses compared to solvent SBM. Distillers dried grains plus solubles responses are frequent if the quality is good (no heat damage, light in color). Blood meal, meat and bone meal, and feather meal give small or inconsistent responses and, when considering high probability of some depression in milk protein percentage, may not be worth a premium over equivalent cost of protein and energy in soybean meal and corn.

Although payoff expectations are not great, it is advisable to calculate estimated degradable and undegradable protein amounts and percentages for rations. Many dairymen overfeed on protein, for example they may feed diets that 20% crude protein (100% dry matter basis, 18% on air dry basis), when 17 to 18% would be plenty if the balance between degradable and undegradable is appropriate. Many times, the extra protein being wasted is degradable and savings could be made by cutting back on protein. This is particularly true if an investment in bypass supplements already is being made and possible savings from reduced use of more degradable supplements are not being realized.

Expect Only 2 to 3 lb Extra Milk per Day from Supplemental Fat

Dietary fat is supplemented in diets for lactating dairy cows to increase dietary energy concentration, e.g., Mcal NE_L/lb dietary dry matter (DM), and, hopefully, energy intake. In most cases, feed costs are increased by adding fat to diets but extra milk production is expected to more than offset increased costs. Some have concluded that improved body condition and improved reproductive performance may be secondary benefits to supplemental fat.

With a best case scenario where all of the added energy is diverted to gain in milk, the amount of response expected to dietary supplementation with fat can be 5 lb of milk per cow daily or more in mature cows with some increase in milk fat percentage as well giving up to 6 lb/day more fat-corrected-milk (FCM). There has been great variation, however, in the amount of response observed in controlled experiments. In a review of 74 research papers, only a few of the responses were equal to the best case scenario.

Tallow has given a fairly consistent response in milk yield but not as much as a best case scenario where all of the added energy was directed to producing more milk. If a pound of tallow were fed daily in place of 1.0 lb of dry matter from corn and that energy transferred to added milk production, the extra energy consumption of 1.75 Mcal (2.64 Mcal added from tallow less .89 Mcal replaced in corn) would be expected to increase milk yield about 5.6 lb per day (1.75 Mcal/.31 Mcal per lb milk). This amount of increase is about equal to the best case scenario described earlier. In reality, we estimate from our experiments and other experiments reviewed that the return in milk production would be about 2.0 lb per day. Our experience with bypass fats, such as Megalac®, has been about the same.

With milk prices at 13 cents/lb, feeding tallow at 20 cents/lb would show a modest profit if 2.0 lb/day increase in milk yield were achieved. Milk value gained over tallow cost per cow would be 6 cents/day. At higher milk prices and high production per cow, the odds of greater profitability should improve.

Effects on Reproduction. Another possible return from feeding supplemental fat is improved reproduction. Returns from improved cow condition and reproduction Several experiments suggest that dietary fat helps to get cows in a positive energy balance sooner which relates to earlier heats and improved pregnancy rates. Feeding of bypass fats, like Megalac® stimulated ovarian follicle development beyond that simply attributable to increased energy. Additionally, key fatty acids that are critical for regulating prostaglandin synthesis may have value in improving embryo survival.

Data suggesting reproduction benefits are not extensive enough to count on with high probability. Thus, we need more information before we can recommend fat based on gains in reproduction. To get better information, we are wanting to do field studies on three or more Florida dairies who have an interest in seeing if investing in supplemental fat gives them returns through increased milk yield and better reproductive performance.

Don't Overvalue Whole Cottonseed.

Previous studies and recent research at the University of Florida show that often there is a depression in milk yield, milk fat percentage, or both caused by WCS particularly when corn silage is the only forage. The negative effects of WCS were overcome when 50% or more of dietary forage (25% or more of total diet DM) was replaced with alfalfa hay or alfalfa haylage. It is uncertain whether other types of legume or grass forages are as effective as alfalfa.

Obviously, WCS is a good feedstuff or it would not be utilized as widely as it is across the country. However, many dairymen perceive the value of WCS to be greater than its true value in the diets they are feeding. Effects of WCS most often appear to be neutral and occasionally negative as compared to the amount of corn and soybean meal energy that it replaced in the diet. Only occasionally has milk yield been higher than that obtained from similar diets without WCS.

If the effect of WCS was neutral (no change in milk production), that indicates that the net energy value of WCS was essentially the same as corn. A relative value of WCS in this case could be calculated by how much it would cost to replace the energy (and extra protein) of WCS with corn and soybean meal. With corn at $115/ton and 49% soybean meal at $220/ton, the energy and protein in one ton of WCS could be replaced for $144. This is a relative value indicating that if WCS costs more than $144/ton it is not a good feed buy. If corn were $120 and soybean meal $250/ton, the relative value, or break even price, goes up to $156 for WCS. In some cases the value of WCS appears to be slightly less than this based on milk yield response. In our most recent experiment at the University of Florida, feeding WCS at 12.5% of diet dry matter (about 6.5 lb. WCS per cow per day) actually depressed milk yield 2.2 lb per day.

Don't Overfeed Phosphorus

Shaver and Howard (1995) make a case in the April 10, 1995 issue of *Hoard's Dairyman* that many dairymen are feeding too much phosphorus relative to needs and that it costs money and results in greater phosphorus excretion in manure which is an environmental concern in some regions, for example the Lake Okeechobee area. This point was made by Florida workers a few years ago as a result of the research of Morse et al. ( ). Shaver and Howard (1995) suggest that reducing diet phosphorus levels from .05 percentage units (e.g., from .50% to .45% of DM) can result in a saving of up to $7.50 per cow per lactation. That was based on a dicalcium phosphate cost of $18 per hundredweight. Even if our costs for phosphorus are cheaper, feeding less is advised for environmental reasons.

Scrutinize Other Additives

Although a review of individual additives will not be made here, most feed additives are not a guarantee for higher milk yield or improved herd health. Use of additives such as supplemental vitamins, buffers, yeast cultures, aspergillus oryzae, zinc methionine, zinc and copper proteinates, methionine hydroxy analog, direct fed microbials, protected amino acids, and others has depended on response enough of the time to be of benefit more times than not or to give extra assurance to the dairyman. Buffers, for example, often are fed to reduce risk of acidosis but may not be as important when feeding manager feels assured that effective fiber intake is optimum. The recommendation here is to make sure that the reasons extra additives are included in a particular diet are known along with the expected returns. Having used an additive successfully in one circumstance may not mean that investment is good in all subsequent situations.

Selected References

Adams, A. L., B. Harris, Jr., H. H. Van Horn, and C. J. Wilcox. 1995. Effects of varying forage types on milk production responses to whole cottonseed, tallow, and yeast. J. Dairy Sci. 78:573.

Beauchemin, K. A. 1991. Effects of dietary neutral detergent fiber concentration and alfalfa hay quality on chewing, rumen function, and milk production of dairy cows. J. Dairy Sci. 74:3140.

Briceno, J. V., H. H. Van Horn, B. Harris, Jr. and C. J. Wilcox. 1987. Effects of neutral detergent fiber and roughage source on dry matter intake and milk yield and composition of dairy cows. J. Dairy Sci. 70:298-308.

Harris, B., Jr., H. H. Van Horn, K. E. Manookian, S. P. Marshall, M. J. Taylor and C. J. Wilcox. 1984. Sugarcane silage, sodium hydroxide and steam pressure-treated sugarcane bagasse, corn silage, cottonseed hulls, sodium bicarbonate, and Aspergillus oryzae product in complete rations for lactating cows. J. Dairy Science 66:1474-1485.

Hutjens, M. F. 1992. Selecting feed additives. Pages 309-317 *in* Large Dairy Herd Management (eds. Van Horn and Wilcox), American Dairy Science Assoc., Champaign, IL.

Mertens, D. R. 1992. Nonstructural and structural carbohydrates. Page 219 *in* Large Dairy Herd Management. Amer. Dairy Sci. Assoc., Urbana, IL.

Morales, J. L., H. H. Van Horn, and J. E. Moore. Dietary interaction of cane molasses with source of roughage: Intake and lactation effects. J. Dairy Science. 72:2331-2338. 1989.

Morse, D., H. H. Head, C. J. Wilcox, H. H. Van Horn, C. D. Hissem, and B. Harris, Jr. 1992. Effects of concentration of dietary phosphorus on amount and route of excretion. J. Dairy Sci. 75:3039.

Poore, M. H., J. A. Moore, R. S. Swingle, T. P. Eck, and W. H. Brown. 1991. wheat straw or alfalfa hay n diets with 30% neutral detergent fiber for actating Holstein cows. J. Dairy Sci. 74:3152.

Shaver, R., and W. Terry Howard. 1995. Are we feeding too much phosphorus? Hoard's Dairyman, April 10, 1995, pp. 280-281.

Shaver, R. D., L. D. Satter, and N. A. Jorgensen. 1988. Impact of forage fiber content on digestion and digesta passage in lactating dairy cows. J. Dairy Sci. 71:1556.

Smith, W. A., B. Harris, Jr., H. H. Van Horn, and C. J. Wilcox. 1993. Effects of forage type on production of dairy cows supplemented with whole cottonseed, tallow, and yeast. J. Dairy Sci. 76:205.

Staples, C. R., E. Bernal, T. M. Ruiz, D. Hissem, C. J. Wilcox, and R. N. Gallaher. 1992. Incorporation of alfalfa hay into five different roughage-based diets for lactating dairy cows. Page 123 *in* Proc. 29th Florida Dairy Production Conf., Univ. Florida, Gainesville.

Tomlinson, A. P., H. H. Van Horn, C. J. Wilcox, and B. Harris, Jr. 1994. Effects of undegradable protein and supplemental fat on milk yield and composition and physiological responses of cows. J. Dairy Sci. 77:145.

Van Horn, H. H., O. Blanco, B. Harris, Jr., and D. K. Beede. 1985. Interaction of protein percent with energy density and protein source in diets for lactating cows. J. Dairy Science 68:1682.

Van Horn, H. H., B. Harris, Jr., M. J. Taylor, K. C. Bachman, and C. J. Wilcox. 1984. By-product feeds for lactating dairy cows: effects of cottonseed hulls, sunflower hulls, corrugated paper, peanut hulls, sugarcane bagasse, and whole cottonseed with additives of fat, sodium bicarbonate and *Aspergillus oryzae* product on milk production. J. Dairy Sci. 67:2922.