IMPACT OF THE ETHANOL INDUSTRY ON THE MOST ECONOMICAL WAY TO FEED YOUR COWS.

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INTRODUCTION

Distillers grains have long been recognized as a valuable supplement for lactating dairy cattle due to its rumen undegraded protein and fat content. Distillers dried grains with solubles (DDGS) has long been a very common ingredient in dairy cattle concentrate mixtures, but generally at modest levels. As ethanol production increases, the price of distillers grains makes it an attractive feed at much higher levels in the dairy diet. Increased use of corn for ethanol raises corn prices and substitution of corn acreage for soybean acreage can increase soybean prices. This in turn can raise the prices for energy and protein in animal diets. Also increased demand for oils for biodiesel can raise the cost of fat sources. As distillers grains provides energy, fat and protein, these trends tend to raise the value of distillers grains as well, but increased supply of distillers grains can help keep prices for this commodity relatively lower than other sources of the same nutrients. Diets with 20% or more of diet dry matter from distillers grains have been fed successfully in more than one research trial. In practice, uncertainty about the exact nutrient composition of distillers grains, and the inability (or unwillingness) to adapt the remainder of the diet to complement high levels of distillers grains, puts tighter constraints on its inclusion rate. In general the limitations of feeding distillers grains are the low lysine content of the undegradable protein (an inherent property of the Zein protein from the endosperm but made even worse if the feed is heated to harshly), its relatively rich content of free, largely unsaturated oil, and its Phosphorous content. While RUP, fat and P are pluses of distillers when present as a minor component to supplement the diet, they can represent challenges when trying to maximize its use to reduce feed cost.

CORN TO ETHANOL PROCESSES

The booming business of converting corn to ethanol is based primarily on a relatively simple process that is often called dry milling but more correctly should be called dry grinding. Milling implies a mechanical separation of constituents of the grain which does not happen in typical ethanol production. True dry milling of corn really does occur in processing corn for human foods with byproduct animal feeds like hominy feed and corn bran resulting from this non-ethanol dry milling process. Although modern dry grind ethanol plants, with their stainless steel and state of the art computerized control and inventory systems, are more efficient than their backwoods ancestors, the basic process is not fundamentally changed. Dry shelled corn is ground, mixed with enzymes to break down the corn starch to glucose, and fermented by yeast (mashing process). The resulting 'beer' is distilled to yield ethanol. Most of the starch is thereby removed as ethanol and carbon dioxide leaving behind the remainder of the corn fiber, protein, ash and fat in the whole stillage. If a bushel of corn contains 34 pounds of starch and 92% of this is hydrolyzed (adding 3.5 pounds of water) and fermented, 17.1 pounds of carbon dioxide and

17.9 pounds of ethanol (2.8 gallons) are produced. The remaining corn components are distributed in an easily removed 'cake' or coarse grain fraction and in a dilute solution of nutrients dissolved or dispersed in water ('thin stillage'). The thin stillage is concentrated by evaporators to yield a condensed syrup or 'solubles'. When the cake and solubles are combined and dried, distillers dried grains with solubles (DDGS) are formed. The ratio of dry matter is somewhere in the vicinity of 50:50 in these two fractions of the whole stillage. The yields of these fractions, expressed relative to the original corn DM, are therefore approximately 1/3 ethanol, 1/3 carbon dioxide, 1/6 distillers grains (without solubles) and 1/6 solubles on a DM basis. Either byproduct stream could be sold separately, as distillers grains and condensed distillers solubles, but it is most common for most of the two streams to be combined. By definition, distillers dried grains with solubles contains at least 3/4 of the whole stillage dry matter produced. With a 50:50 production of cake and solubles, theoretically DDGS could contain 1/3 cake with 2/3 soluble to 2/3 cake with 1/3 soluble and meet this definition. In practice, the range is more likely to fall between 50:50 cake and solubles and 2/3 cake with 1/3 solubles, with excess solubles sold or utilized for some other purpose whenever the DDGS contains less than 50% solubles. Distillers wet grains is defined more loosely but contains solubles even though it doesn't explicitly appear in the name and there is no official definition for wet distillers grains with solubles. A plant that routinely diverts solubles from the combined distillers grains and soluble stream will produce a distillers grains product lower in fat and P, and higher in NDF. We know of one plant in Minnesota that is burning solubles in a fluidized bed to generate heat for the plant. Other plants in Wisconsin are selling some solubles to dairy farms for addition to their on farm methane digesters. In general, lowering the solubles content would produce a feed more compatible with high inclusion levels in most lactating cow rations.

Maillard products form during drying of distillers products. Higher heat, slower cooling and the presence of reducing sugars from the solubles all enhance this process. Some Maillard reaction might be useful, causing DDGS to have a higher RUP and lower RDP than wet distillers grains, but at high levels of distillers grains in the diet, RUP limitation (at least in quantity) is not really likely to be an issue. In general the negative aspects of Maillard products will be to reduce total lysine and lysine availability in the RUP of distillers grains, resulting in a lower quality of the RUP in DDGS which clearly may be a problem at high levels of inclusion.

Although condensed solubles are a liquid, and wet cake is a soggy solid, the DM content of the solubles may actually be greater than that of the wet cake. Modified wet distillers are distillers wet grains that have undergone partial drum drying and generally run about 50% DM. These are generally produced in ethanol plants using Fagan technology. Some wet cake may be dried in the presence of lower amounts of solubles to a DM above 50%, and then have solubles added back. This separates some of the heat from the reducing sugars and may have some affect on the extent of the Maillard reactions.

Traditional wet milling of corn is the process whereby corn starch, corn sweeteners, corn germ, corn gluten meal, and corn gluten feed are produced. In wet milling the fibrous outer coat of the corn grain (the pericarp or bran, rich in fiber), the germ (rich in fat and protein), and the endosperm are separated. The endosperm is also physically separated into a protein fraction and a relatively pure starch fraction. It is this starch fraction that is used to generate starch, or corn syrup. The resulting relatively pure starch can also be fermented to produce ethanol. In this case, a very pure substrate is being fermented so little residue is left from the fermentation process and the main byproducts are the gluten feed (bran plus concentrated steep water), gluten meal, and corn germ. The corn germ can be processed to form corn oil and corn germ meal. This is a flexible but energy intensive process and the plants that do this are much larger than the typical 40-80 million gallon/year dry grind ethanol plants currently proliferating. Corn germ protein is higher in lysine and less degradable than the residual protein in the endosperm.

Recently several 'add ons' to the basic dry grind distilling process have been introduced. Many of these processes mimic the steps in wet milling because, prior to mashing and fermentation, dry shelled corn is physically separated into a high fiber barn, germ, and endosperm. These processes are designed to generate a starch enriched substrate for the fermentation tanks to increase the ethanol titer and yield of ethanol per fermentation tank. The endosperm stream is not as pure as the starch slurry generated by traditional wet milling as it still contains the endosperm protein which would have been separated as gluten meal in the traditional wet milling process. The starch is then removed from the endosperm by fermentation. The process will yield less ethanol per bushel of corn than wet milling or dry grind because some starch still remains in the bran and germ fractions. One other complication is that these processes may be wet (the Solaris process is one example) or various forms of dry processing as used in the Broin BFrac system or other true dry milling processes.

Many products can arise from these new processes. They will differ in starch content based on the effectiveness of the different milling process in separating components and will contain more starch than standard DDGS. The composition of the feeds sold also will depend greatly on how various streams are recombined to meet different markets. From the pre-fermentation physical milling processes we can obtain a high fiber feed from the bran, plus either a whole germ or a defatted germ meal if the oil is extracted. The whole stillage resulting from fermentation of the 'purified' endosperm will also contain a solid residue and condensed solubles or syrup, but these will differ from the syrup and cake produced from the dry grind process. These fermentation residues will be lower in fiber and fat, as well as lower in P, than the typical cake and solubles obtained by fermenting the entire grain, and will also be higher in protein. In addition the protein in these fermentation residues comes from the endosperm only and is therefore likely to be more rumen undegradable and lower in lysine than DDGS, while the germ or germ meal will be just the opposite (higher rumen degradability and higher lysine). It is too bad that the high RUP feed doesn't have more lysine, but unfortunately that is the result of the basic nature of corn Zein protein and not a result of the ethanol process itself. Given the multitude of streams coming off with these new pre-fermentation milling techniques, it is easy to see that they can be combined in any number of combinations and different proportions. If they are all combined together, the resulting feed should be similar to DDGS, but with more residual starch. Officially, parts of the corn that have not gone through the fermentation process cannot be called distillers grains, so the naming and marketing of the various hybrid products will no doubt become confusing. What is important for feeding dairy cows is to have an accurate estimate of the starch, crude protein, fat (actual, not minimum), neutral detergent fiber and phosphorous content of the feed. Even then, protein degradability, true fatty aid content, NDF digestibility and lysine content are likely to remain unknown.

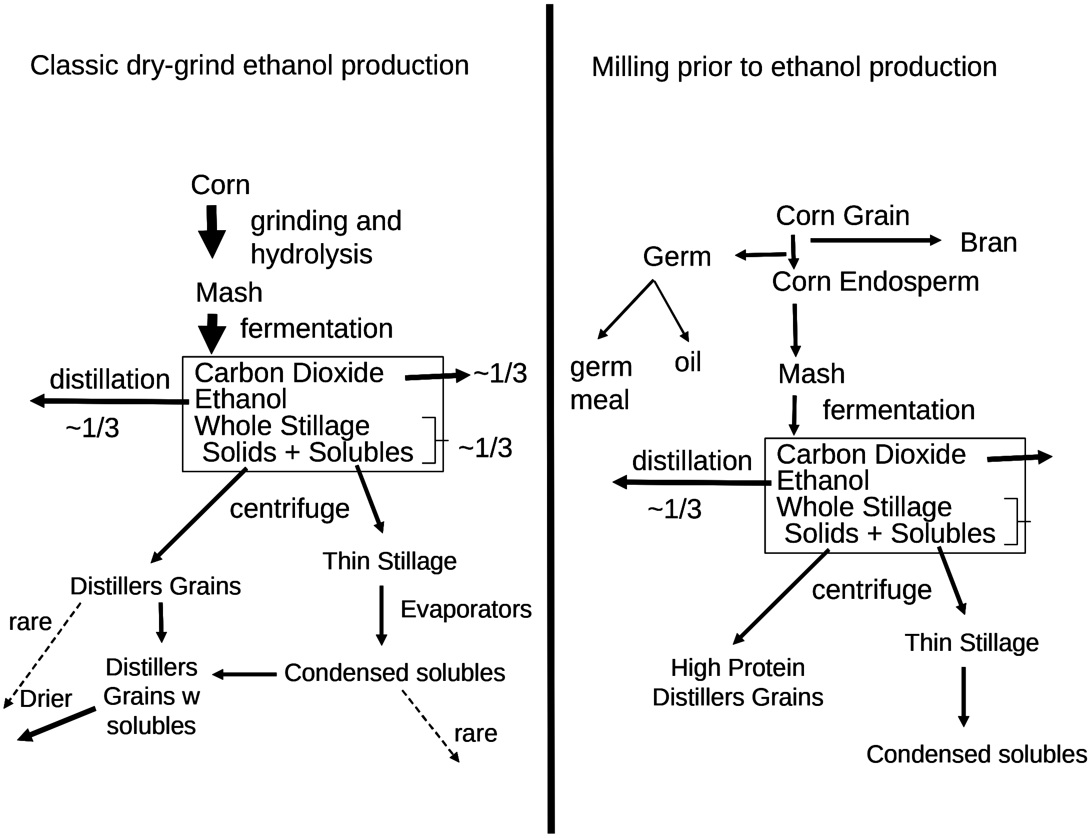


Figure 1: On the left is the classic dry grind process where the entire kernel is subject to hydrolysis and fermentation. On the right the separation of germ and bran from the endosperm by some milling process precedes hydrolysis and fermentation of the endosperm, resulting in multiple streams that can be recombined in various forms.

An alternative process that will result in a reduced fat DDGS is an add-on to the back end of the dry milling process. Glacial Lakes Energy in Watertown SD is removing a portion of the fat from the dissolved solids obtained after fermentation of the whole grain. If this could be done effectively it would seem to be an ideal way to lower the fat content of the resulting distillers grains and also provide a fat stream for biodiesel or oil production. From informal reports, it does not seem that fat yields are very high at this point, but even a slight reduction in fat content of distillers should improve its potential inclusion rate in many dairy diets. Although P content would still remain a problem, it is one of nutrient management not of animal performance. If dairy manure can be used on acres growing corn for nearby ethanol plants, a sustainable loop could be formed to utilize this phosphorous in an environmentally responsible way. It is possible that in the future other post fermentation modifications of the solubles or cake could be developed which would provide an additional source of variation to products of the dry grind or pre-milling processes.

CHEMICAL CONTENT AND OPPORTUNITIES

Variation in the chemical content of 'standard' DDGS and Wet DG is a significant issue in its practical use. Variation in techniques used to measure the composition is also a problem and leads to overestimation of the true variability in DG. This is especially true for the ether extract or crude fat content of the feed. Recently the ethanol industry has proclaimed standard assay methods, but the widespread adoption of these is unknown and lab variation will still exist. Use of a consistent and accurate assay of various byproduct streams will become even more important as new and different processes are adopted. The new products represent new opportunities for using distillers grains. Low fat, low protein and low P corn bran fractions could be included in dairy rations in large amounts. Proteins from the endosperm residue and germ meal could be blended to better match the RDP and lysine requirement of the cow and content of other feeds used. Corn oil, if priced right, could be adjusted independently to provide an optimum return. Plants have an opportunity to monitor and blend products to provide a more consistent and targeted feed. However, if using up all of the end products is still the primary goal of the ethanol plants, there will be less flexibility to provide a consistent and desirable product tailored to dairy cattle.

The carbohydrate content of a feed can be divided into Neutral Detergent Fiber and non-fiber carbohydrate. Nonfiber carbohydrate can be further divided into starch, total ethanol soluble carbohydrates which are simple sugars and oligosaccharides, and soluble fiber. In corn grain, almost all of the NFC is starch. Care must be taken when determining the NFC content of Distillers grains. The NDFCP fraction of distillers grains can be large, especially if the NDF analysis procedure used does not include sulfite. When calculating the NFC content of distillers grains it is important to use the formula that corrects for the double counting of NDFCP in the NDF and CP fraction, that is NFC = DM - ash - NDF - CP + NDFCP. The NDF and NDFCP must be analyzed using the same NDF procedure, either both with sulfite or both without. It is not unreasonable to perform an NDF procedure without sulfite to determine NDFCP. NDFCP has been used as an indicator of the amount of heat damage and Maillard products that may have been formed. Because sulfite dissolves some of these, NDFCP without sulfite will be a larger fraction, and arguably a more sensitive measure of heat damage. However, if the NDF value is derived with sulfite and the NDFCP is derived without sulfite, and these values are plugged into the NFC equation given above, the value for NFC will be overestimated. Analysis of distillers grains are given in the following figures and tables.

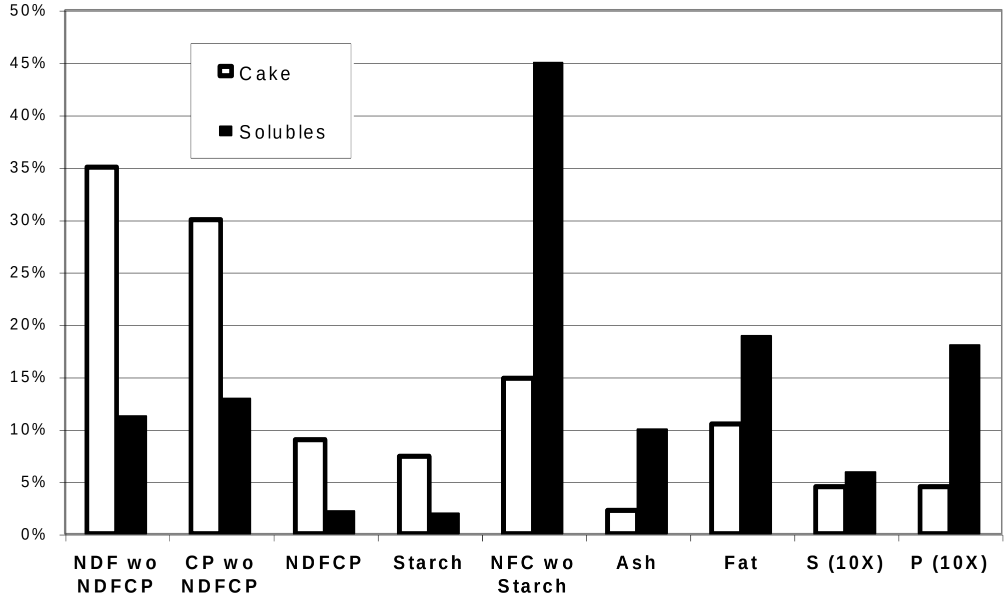


Figure 2: Analysis of the cake and solubles stream from standard dry grind ethanol production from corn. Data are from one plant used as an example.

	Grain%	Germ%	Bran%	Endosperm%
Kernel DM	**100**	**11.1**	**6.1**	**82.9**
Starch	73.4	8.3	7.0	87.6
Protein	9.1	18.4	4.5	8.0
Oil	4.4	33.2	1.1	0.8
Ash	1.4	10.5	0.9	0.3
Sugars	1.9	10.8	0.5	0.6
NDF	9.5	11.0	90	?
Residual(?)	.3	7.8	0	2.7
Phosphorus	0.29	1.33	0.42	0.14
Lysine (%CP)	2.84	4.8		1.6

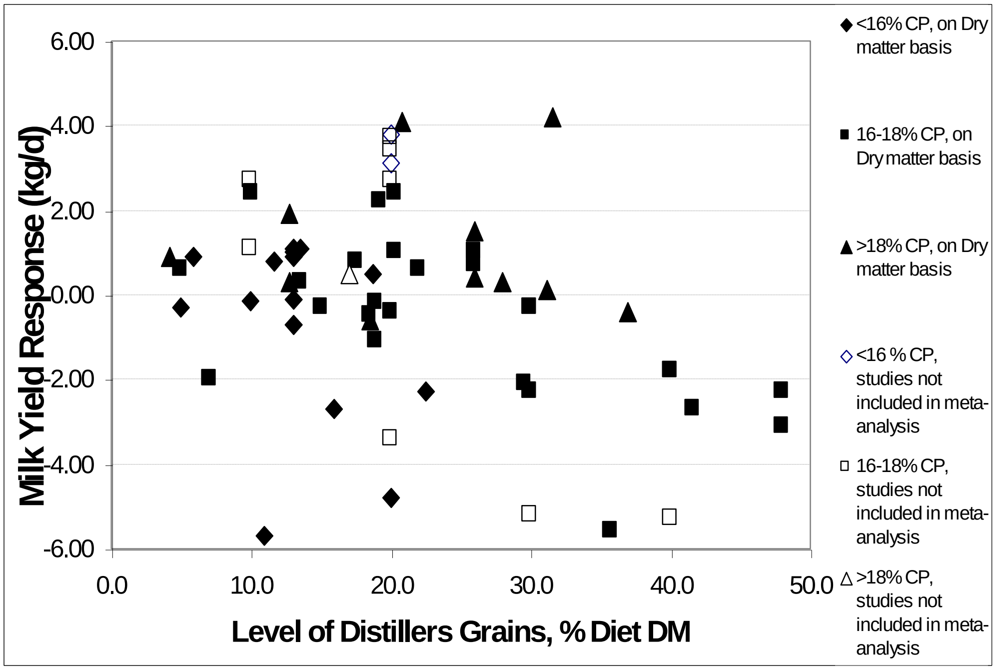
Table 1: Composition of whole corn kernel and carefully dissected parts. Actual milling fractions are likely to contain more starch in the germ and bran. Adapted from Corn Chemistry and Technology, P.J. White and L.A. Johnson, second edition, 2003

Table 2: This shows the theoretical results of removing starch from the grain or from the pure endosperm, and also removing oil from the pure germ. In actual milled products the starch removal by milling is not likely to be complete but removal by fermentation will be very high.

	Grain – Starch	Germ – Oil	Endosperm – Starch
	DGS?	Germ meal	Gluten meal?
Starch%	0	14.6	0
Protein%	34.2	32.4	64.5
Oil%	16.5	0	6.5
Ash%	5.3	18.5	2.4
Sugars%	7.1	19.0	4.8
NDF%	34.4	16.5	
Phosphorus%	1.1	1.99	1.1
Lysine (%CP)	2.84	4.8	1.6

RESEARCH EXPERIENCE WITH DISTIILLERS GRAINS

Figure 3: Response of milk yield in response to level of distillers grains fed and protein content of diet. Response was +.60 kg for 5-15%DG, +.14 kg for 16 to 25% DG .14 and -.65 kg for 26 to 48%DG; +1.04 kg for high CP, -.15 kg for mid CP and -.80 kg for low CP.



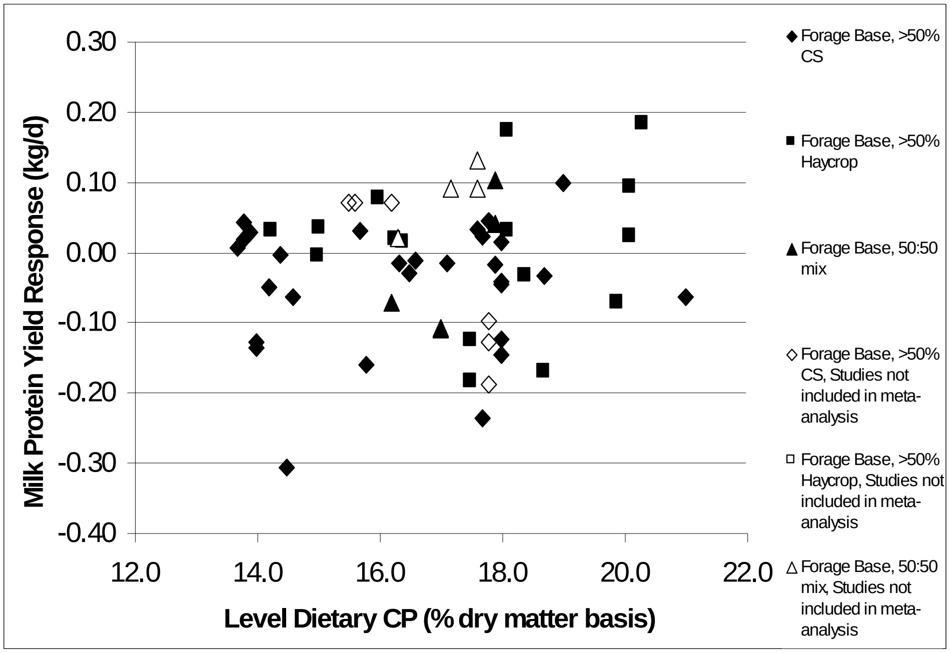
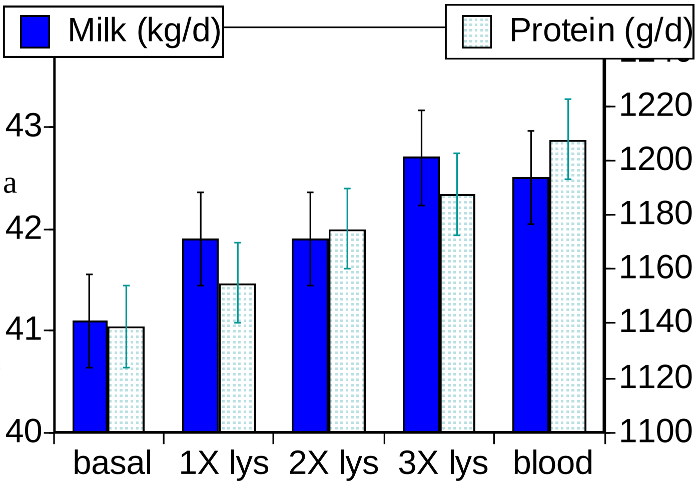


Figure 4: Response of milk protein yield. Yield was +.08, +.032 and +.02 kg/d for high, mid and low CP; -.04, +.13 and +.04 for primarily corn silage, mixed, or primarily hay crop forage.

Numerous research trials have been conducted with distillers grains with solubles. Formal meta-analyses of these data have been conducted, and one example is available at http://www.uwex.edu/ces/dairynutrition/documents/midwestdg305.pdf (Kaiser, Schwab, Shaver and Armentano). The results of these experiments are included in the figures 3, 4, and 6. Inclusion of distillers grains above 25% of the TMR is problematic in most cases. At lower levels of inclusion the response to distillers grains tends to be positive in higher protein diets. The control and distllers grains diets compared were equal in CP, but when both diets were low in CP, the response to DG tends to be negative even at moderate inclusion rates.

Milk protein yield responses are shown as a function of dietary protein and forage base in figure 4. Low CP diets based mainly on corn silage gave negative results more often for milk protein yield and also for dry matter intake (not shown) while inclusion of some significant amounts of hay crop forages in the diet generally resulted in more positive responses. It is likely that higher CP diets help to alleviate problems with the CP in DG. Low CP diets rich in DG may have inadequate degradable CP. Low CP diets are also likely to have DG as the only supplemental protein source, with no high lysine protein sources brought in to correct the lysine deficiency in distillers grains. Response of DG diets to a postruminal supply of synthetic lysine or to blood meal is shown in figure 5 (Armentano, 1996). Response to lysine rich protein sources is not always so clear cut as this and almost certainly depends on the lysine availability in DG as a result of heat damage as well as other dietary components (French et al., 2007).



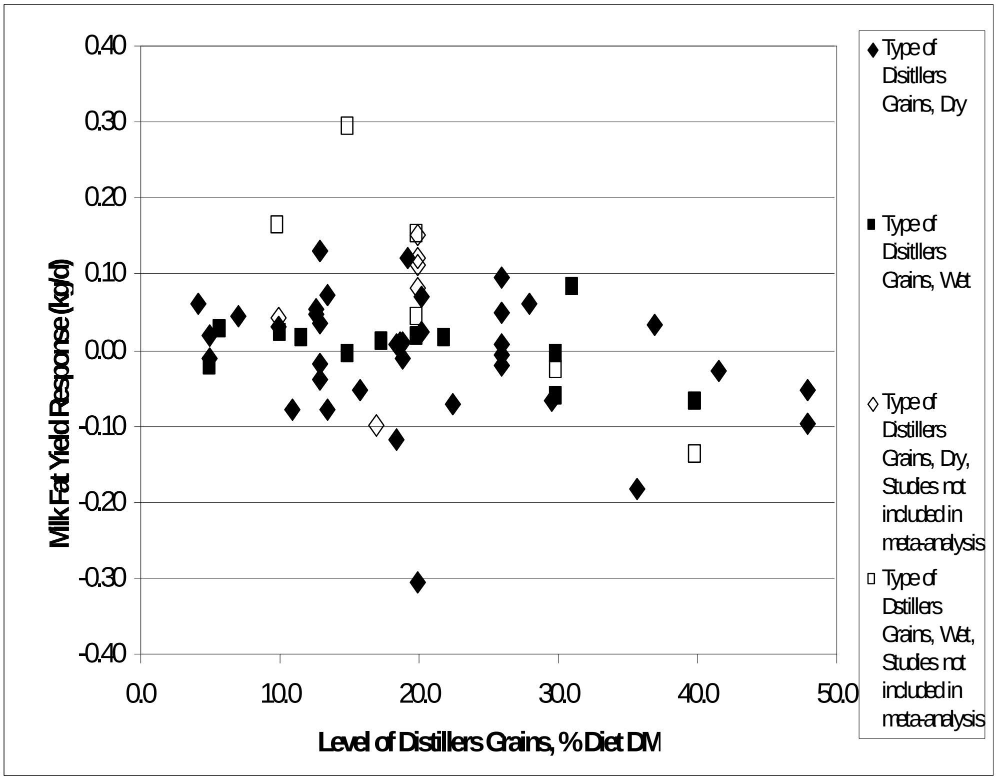


Figure 6: Response of milk fat yield. Yield was +.01, -.-01 and -.06 kg for low, medium and high levels of DG. . Milk fat % was -.11, -.06 and -.02% for low, medium and high levels of DG, a result of dilution. Yield did not differ between wet and dry DG but milk fat concentration was +.02 and -.16% for dry and wet DG

Milk fat yield is plotted in figure 6 relative to level of distiller grains and use of wet or dried grains. There is no indication in this data set for milk fat depression resulting from feeding wet distillers grains vs. dry. The meta analysis did reveal that milk fat concentration was lower for wet distillers grains, and this presumably occurred due to increased milk yield without a corresponding rise in milk fat yield. An important caveat in considering the form of distillers grains is that research trials tend to use a well preserved and consistent source of distillers grains. Feeding wet distillers grains on large farms where batches turnover frequently without having information on the oil content could be a significant means for inducing true milk fat depression if upper limits for free oils are exceeded.

FEEDING DISTILLERS TO LACTATING COWS

Figure 7 highlights the issues that must be addressed when high levels of distillers grains are fed to cows. This figure shows why distillers grains in small amounts in the diet has been used to increase the fat, RUP, CP and NEl of dairy diets. It is also a useful source of chemical, but not physically effective NDF. In small amounts distillers has additional value due to its P and S content. At higher levels of DG these supplementary aspects can become problems of excess from an animal performance perspective (fat, S), from an environmental perspective (CP, P, S). In addition limitation of starch or degradable CP could be an issue.

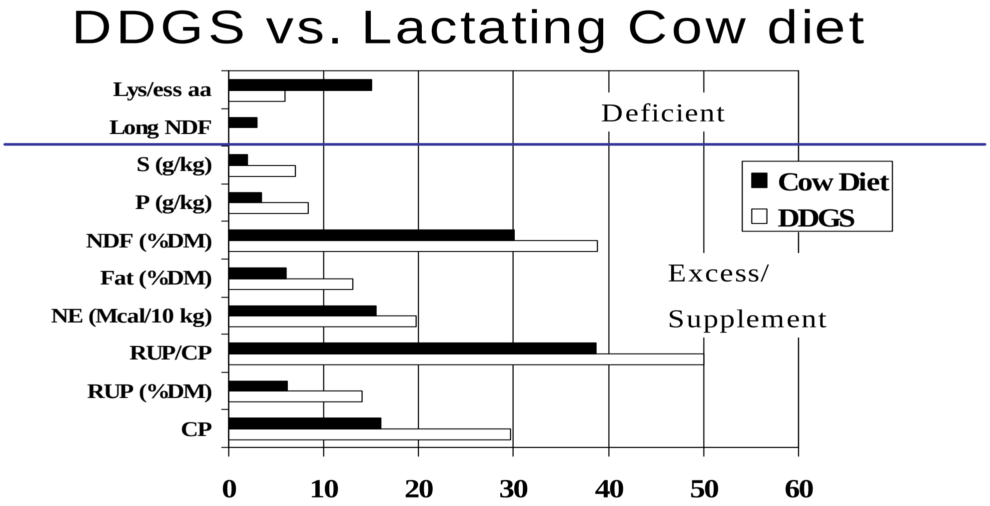


Figure 7: Comparison of the content of distillers grains with solubles to the requirements of a lactating cow.

Table 3 shows results of a trial (Leonardi et al., 2005) where a 15% DDGS diet was compared to either a low fat or iso-fat control diet. This trial shows two important points. First if adding distillers means adding fat, it is possible for milk fat yield to remain constant while milk fat % decreases due to dilution effect of increased milk. The increased milk yield from DG in this case could clearly be due simply to its fat content. The second point is that, although adding fat as free oil or DG did not change gross milk fat yield, it is important to note that short chain milk fatty acid yield were decreased while C18 fatty acids increased. This is most likely due to a depression of fatty acid synthesis by the mammary gland in response to products of partial hydrogenation of oil in the rumen and a simultaneous increased supply of performed dietary C18 to the mammary gland. If oil from DG is added to the diet to replace rumen inert, intestinally digestible fat, a depression in short chain fatty acids that is not compensated for by increased absorption of C18 fatty acids would likely lead to a true reduction in fat yield. This effect of oil in distillers grains is very important because the oil content of distillers grains is highly variable even among batches from the same plant. Fat content can also vary among sources based on process variations noted earlier. Different fatty acid analysis techniques (ether extract vs. acid hydrolysis vs. fatty acid) or the same analysis preformed in different labs may also give different results. Also, the fat analysis reported will be a guaranteed minimum and does little to protect against over feeding of oil.

Table 3.	control	15%DDGS	control+fat
Diet FA, %	3.8	4.8	5.0
Milk*, kg/d	44.6	46.2	47.2
Fat Yield, kg/d	1.49	1.49	1.53
Milk Fat %*	3.38	3.24	3.28
C<16/C18 FA	1.19	0.94	0.93
C<16 FA, g/d	673	614	628
C18, g/d	564	657	677

IMPACT ON COST OF FEEDING COWS

Making maximum profit by feeding cows is a complex balancing act. We must pick a set of feeds that meets the cow's nutrient requirements in the most economical way. This is what least cost ration balancers are designed to do but most people don't really let them do this. How do you cripple a least cost ration balancer?

1. You completely limit access to feeds by not including them as possible feeds in the ration.

2. You limit the amount of a feed you can use by capping the amount of feed in the diet.

3. You force in certain feeds (especially forages or other home-grown feeds) at specified (high) levels based on availability rather than pricing them in by true cost. This then limits the composition of the remainder of the diet resulting in a least cost supplement but not a least cost ration.

Getting around the first problem is really not easy. To consider every possible feed means to provide updated price and nutrient information on a large number of feeds every time you balance a ration and order new feed. It also means you have the exact nutrient composition and price of the feed you would purchase prior to purchasing. That's not likely to happen at the single farm level, although a feed consultant serving a defined region will have a very good idea of what standard feeds should be included and also what new feeds may need to be included because they are a bargain currently. Programs like FeedVal and Sesame are not least cost ration programs, but they are programs that assign a 'neutral' price to a large number of feeds. They do this by using a standard set of feeds (a small set in FeedVal, a larger set in Sesame) with their price and nutrient composition to define the value of specific nutrients and then use the nutrient content of other feeds to determine the dollar value of these other feeds. This is a very good way to screen feeds to see if they should be included in a least cost ration formulation. Feeds that are priced below their 'neutral' value should definitely be offered to the least cost ration balancing program. Note that this type of program assumes that the cow needs all of those nutrients. For example in FeedVal4 a value is placed on P. If you always find yourself buying dicalcium phosphate or rock phosphate it makes sense to include the value of P to evaluate candidate feeds. But if you feed large amounts of feed such as Distillers Grains and you exceed the P requirement of the cow, then you are overvaluing distillers 'neutral' price. If you ignore the value of P in distillers you may be underestimating its 'neutral' price because it very likely will displace some purchased P costs. Their is really no way to get around this problem, but remember that if you use these programs to select candidates for your least cost ration, the least cost ration automatically values the P only until the requirement is met. Obviously using a program like Sesame, with a wide array of standard feeds used to determine the value of nutrients, requires the same effort as updating all the feeds in a least cost ration balancer, so there is a limit to the number of feeds you want to include and still get value from this screening process. Using the shortcut approach of assigning value to only one nutrient (for example the lowest price per pound of protein) ignores the other nutrients in the feed, and this approach will always overestimate the value of concentrated sources of the nutrient picked. In other words when corn gluten meal (60%CP) and DDGS (30%CP) cost the same per pound of protein, DDGS is a much more economical feed because it provides another 30% of DM for free!

Also remember that what a nutritionist does is to increase the value of individual feeds by mixing them with complementary feeds. Eliminating feed A from the diet (or capping its inclusion rate) not only prevents you from benefiting from the low price of feed A, but may also limit the inclusion of a feed B which complements feed A.

Another important aspect is the production response you expect to receive from meeting a nutrient requirement. In a pure economic it makes sense to add a nutrient up to the point where the marginal production response value you receive equals the cost of marginal cost of adding more of the nutrient. By definition this will be below the amount of nutrient that causes maximum production. Requirements are based on achieving maximum production response (actually maximum detectable response) and in practice requirements are set a little above the true measured maximum response level. Another aspect of this is that the imperfect state of our knowledge on cows in general and your specific situation means that there is a risk element that should be figured into the requirement. Least cost rations do not take any of this into account at all.

Having said this, why do people include caps on certain feeds? There are two reasons. First if we do not adequately describe the broad array of 'nutrients' required by the cow, then we can get some funny rations. An example is when forages are relatively expensive and high fiber byproducts are cheap. If we simply put in a requirement for NDF we will get very low forage diets with huge amounts of the high fiber by-product. The typical response to this may be to cap the high fiber byproduct. Don't be surprised if you then have to cap the next high fiber byproduct, then have to cap the sum of the byproducts etc. A better approach is to define a nutrient like 'forage NDF' or physically effective NDF and add that as a required nutrient and not cap any of the byproduct feeds. A similar example would be to cap the free oil content of the diet rather than limiting all feeds that have free oil in them by capping the amounts of these feeds individually. A second reason for capping certain feeds is much more reasonable. Remember that a least cost ration returns the one cheapest diet that meets the requirements. The next cheapest diet may look quite different in the feeds used but may only be just slightly more expensive. If the second diet is one that is much more traditional, it has the advantage of being 'tried and true'. This reduction in risk is certainly worth a small investment. The best way to use least cost rations to detect this is to simply run multiple diets with and without caps and determine the overall ration price.

When a feeds composition is very uncertain, its value decreases. This is because the minimum requirements must be raise to ensure maximum (or near maximum) productivity by the cows. Although there are more sophisticated mathematical ways to handle this, this is the most typical approach to the problem. Therefore a feed that is delivered with good information on its actual nutrient content is worth more if you can rely on this information. Remember some valuable nutrients (like oil and P in DDGS) may actually be excessive. If you establish both a minimum level of fat, and a maximum level of free oil, this may totally eliminate using a feed whose variation in fat can violate the ceiling when high and the requirement when low.

In addition to caps, we have the opposite which is the minimum inclusion rate. Minimum or fixed inclusion rates are most typically applied to forages in order to manage inventories of stored forage and adequate feed out rate of ensiled feeds to maintain quality. This is a totally reasonable thing to do within a harvest year. However, consistently forcing in forages at specified levels into a 'least cost' ration is a common mistake in my opinion. For the nutritionist newly arrived on a farm, there is little option but to use the forage inventories available. But the producer must consult his nutritional and agronomic adviser to define a long term plan for the crop enterprise of the farm and the cost of production of home grown forages should be estimated as accurately as possible. This is especially true when considering high fiber feeds that arise from ethanol production as these feeds may reduce the level of forage needed (and possibly the amount that can be tolerated) in the diet to meet fiber requirements of the cow. Also if lower starch feeds will be purchased, the forage base may be logically shifted towards corn silage and away from grass and legume forages in areas where corn silage is profitably grown.

Again, you cannot make sound decisions on the most economic diet unless you have a true cost figure for each feed in the diet. This most certainly includes home grown feeds, none of which are free. It is important to separate the feed growing enterprise on your farm from the cow feeding enterprise. Even if you plan to feed forages at a fixed rate, it is a good exercise to run a least cost program with an honest cost assigned to the forages and allow the forage amount to vary. If the program feeds less forage than you are forcing, it is telling you something important about your cost of purchased vs. produced feed. Remember to include feed out and storage losses associated with wet or ensiled feeds and for feeds stored in commodity structures subject to feed loss or wastage.

There is also great value in including a diverse set of feeds. From an agronomic point of view with home grown feeds this may relate to optimum crop rotations and risks of poor harvests being crop specific. From a purchased feed perspective using multiple feeds minimizes the impact of erroneous nutritional information of any one feed. The most reasonable way to do this is in fact to cap the amount of each feed in the ration. I would suggest that when this approach is used, the ration should be rerun without the caps so that you know what the caps costs you.

Avoiding ratios. In general the use of ratios of two nutrients to balance diets should be avoided. Two good examples are expressing RUP as a % of CP or forage NDF as a % of ration NDF. Expressing the CP requirement as 17%CP and 35% of the CP as RUP seems like the same thing as requiring the diet DM to be 6% RUP and 11% RDP. Its not and the latter is much better. Why? Imagine you have a forage that is 25% CP and 20% of this is RUP and a concentrate that is 9% CP with 85% of the CP as RUP. If you want to feed 60% of this forage, the TMR would contain 6.1% RUP and 12.5% RDP meaning we meet the RUP requirement and are overfeeding RDP. However the RUP as % of CP is less than 33%. If you tell your least cost ration balancing program that RUP must be 35% of the CP it will not allow you to formulate this diet, even though providing 6.1% RUP and 12.5% RDP is meeting the animals true requirements (although is wasting Nitrogen by feeding excessive RDP and CP).

Adjusting to changes in feed prices requires allowing the maximum flexibility possible in ration constraints. In the case of Distillers grains in particular, limits should be placed on free oil content of the diet (2% may be reasonable) as well as total ether extract (5 to 6%), and a requirement for physically effective or forage NDF (21% forage NDF) should be included. Also, distillers grains contains very little starch even though it does provide NFC. Based on current research setting a minimum NFC (30% of DM for instance) is probably more justified than setting a minimum starch level, but this is open to argument. Be aware than an NFC minimum and an NDF cap do much the same thing, and both will be highly related to the energy requirement set for the diet. At this time I do not know of a good way to incorporate balancing for lysine in a least cost ration. Avoiding heat damaged distillers grains, limiting the amount of CP that comes from distillers grains, or forcing in high lysine protein sources such as blood meal may improve cow performance but will hamper obtaining a least cost ration. One final note is that lower forage, high fiber diets often yield good results but at higher dry matter intakes. The true cost of a ration must be considered in \$/cow per day rather than \$ per kg of ration DM if differences in feed intake are to be considered.

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