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Nutritional Evaluation of By-product Feeds

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The feedlot industry was founded on feeding by-products. Some of the earliest records of by-products in the United States date back to the early 1900's in Kentucky where cattle were fed brewer's and distiller's wastes. With 40 to 50 distilleries in eastern Kentucky, cattle feeding boomed, until the state was voted dry in 1916 during prohibition (Ball and Cornett, 1996). It is interesting to note that cattle have been fed distillers grains for over 100 years! Distillers grains are currently the 'hot topic' in feedlot cattle nutrition spurred on by ethanol production for the automotive industry, not just by the good old whiskey industry anymore. In Australia, cottonseed by-products have been successfully incorporated into feeding systems for nearly two decades. Indeed there are many successful examples of by-product feeding worldwide.

By-products can be defined as waste materials derived from raw agricultural commodity processing for food or fibre and food manufacturing. Many feed yards consider by-products as a means to cheapen cost of gain of cattle in their feeding programs. A careful and thorough evaluation of by-products is needed between the feedlot nutritionist and manager prior to jumping into the great unknown of using these products. The last thing you want as a feedlot manager is 'nightmare' closeouts when these ingredients are either priced incorrectly or you have not assessed their nutritional value correctly. Sometimes these by-products can work and sometimes they can't. The challenge is to delineate the factors causing the difference in outcomes.

An infinite amount of time could be devoted to discussing the nutritional and economic evaluation of particular by-product feedstuffs available in Australia. A list of by-product feeds marketed in Australia is detailed in Table 1. My recommendation would by to consult your feedlot nutritionist on this matter due to the complexity and time in reviewing this subject matter. To simplify matters, in this paper, key features in determining the nutritional value of by-products will be reviewed.

Key considerations in the evaluation of byproduct feeds include the following:

1. Ingredient Price
    a. Contract size and conditions.
    b. Transport costs to the feedlot.
    c. Shrink: estimated shrink must be factored into the ingredient price landed at the feedlot.
    d. Price relationships to other protein and energy sources.

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Table 1. By-product feedstuffs marketed to the Australian feedlot industry

Energy Sources
palm fatty acid distillate, palm acid oil, recycled cooking oils, tallow, potato waste, hominy, bakery wastes, potato chip waste, chocolate wastes, glycerol, food wastes, tapioca pellets, molasses,
Energy and Roughage Sources
wet corn gluten feed
Roughage Sources
cottonseed, cottonseed hulls, peanut shell, almond hulls, citrus pulp, oat offal, rice bran
Protein Sources
cottonseed meal, soybean meal, sunflower meal, canola meal, copra meal, palm kernel meal, peanut meal, macadamia meal
Protein and Energy sources
wet distillers grains and solubles, wet distillers grains, wet distillers solubles, corn steep liquor, dried distillers grains, wheat middlings or mill run wheat, malt combings
Protein, Energy and Roughage Sources
Whole cottonseed

2. Dry matter
    a. Ingredient dry matter price: the dry matter cost landed at the feedlot should always be evaluated, not the as-fed cost at the ingredients point of origin. It is recommended that all feedlots have a drying oven and a standardised dry matter testing procedure for daily testing of ingredients. Contracts specifying minimum standards for dry matter should be developed. Tremendous economic losses can be sustained if you are receiving product wetter than contractually specified.
    b. Shelf Life: The wetter the ingredient, the more susceptible the ingredient often is to shrink through evaporation and aerobic respiration. Shelf life and spoilage of high moisture ingredients is often accelerated in environmental conditions in Australia. Spoiled product negatively affects feed bunk hygiene and ration palatability. Oxidative rancidity may be of concern in some fat products.
    c. Storage Cost: Wet ingredients also may have a higher storage cost if they have to be ensiled or bagged to minimize aerobic spoilage. These costs must be taken into account.

3. Nutrient Composition
    a. Chemical composition: Commonly available nutrients (energy, protein, minerals and vitamins) of by-products can be found in publications such as the Nutrients Requirements of Beef Cattle (NRC, 1996) or the annual Beef Magazine Feed Composition Tables. If you are dealing with a variable by-product it is recommended that laboratory analysis is conducted on a number of random samples. It is recommended all feedlots have a scheduled ingredient analysis program.
    b. Nutrient availability: some by-byproduct feeds that are heat damaged may contain acid detergent insoluble protein which is not available to rumen fermentation or digestion and absorption in the small intestine.
    c. Cost per unit of dietary nutrient e.g. Net Energy for Gain (NEg), Crude Protein, Neutral Detergent Fibre, etc: this is a key factor in comparing ingredient sources.
    d. Nutrient Tradeoffs: the nutrient composition of a by-product may lessen or increase the need for other nutrients sources to be added to the ration formulation, and thus may decrease or increase the cost of the final ration. All by-products must be evaluated in a formulation program to determine the best-cost ration.

4. Palatability: Palatability is a function of how the feed looks to the animal (i.e., sight), and of odor, taste, and texture. Palatability is an example of a variable not completely described by nutrient analysis that is consequently difficult to quantify (Pritchard and Stateler, 1997).

Feeding preference tests are commonly used to assess palatability. The depressive effects of mold of fecal contamination of feed can be observed on a daily basis in any feedlot.

5. Consistency: Some by-products are notoriously variable for the very fact that they are waste materials. Quality control in manufacture in often lax. If this is the case with your by-product you need to work with your feedlot nutritionist on how to incorporate inherent nutrient variability into ingredient price models. By the same token, some by-products are very consistent (e.g. cottonseed by-products) and replicable responses to by-product utilisation can be expected.
    a. Supply: This is a major downfall of many by-products. Large feedlots need continuity in supply of ingredients, and if this is not available it is probably not worth using the product intermittently to the cattle's detriment, especially if intake is negatively affected. Contingencies on site e.g. storage of excess material in AG-BAG's may lessen problems in the variability of supply.
    b. Dry Matter: Minimum standards for dry matter should be written into contracts.
    c. Nutrient Composition: Minimum standards for the nutrients of interest (e.g. crude protein, ether extract, etc.) should be written into contracts. Maximum standards for free fatty acids and insoluble material should be written into all oil contracts. In areas where by-product streams are being added together such as wet distillers grains with solubles, it is important that approximately the same amount of each stream (wet distillers grains + solubles) are added together, otherwise inconsistency in nutrient composition of composite WDGS will occur. A recent survey conducted at the University of Nebraska in which WDGS was sampled from 6 plants during two consecutive 5 day periods indicated substantial variation in DM, sulfur and fat contents with coefficient of variation within plants ranging from 1.5 to 7.1% for DM, 2.3 to 8.8 for fat, and 3.6 to 36.3% for sulphur. Ethanol plants that pay special attention to marketing products for feedlots and stabilising their manufacturing process, however can achieve excellent results. Internal data we have obtained from a major ethanol plant in Hereford, Texas for a 20/80% sorghum-corn WDGS composite on 69 consecutive daily samples from January to April, 2009 are detailed below (Table 2). Coefficients of variation of below 5, for moisture, crude protein and fat indicate excellent quality control and stability in manufacture of these by-products.

Table 2. Laboratory Analyses basis of WDGS composite expressed on a dry matter from Hereford, Texas.

Statistic	Moisture, %	Crude Protein, %	Crude Fat, %	NEg, Mcal/lb	K, %	S, %
Average	64.92	31.03	11.51	0.561	0.894	0.656
Std. Dev. ±	0.47	0.83	0.32	0.013	0.07	0.054
CV, %	0.72	2.68	2.77	2.31	7.84	8.23

    d. Shelf Life: Presence of moldy, rancid or off-colour product should be noted and rejected.

6. Antinutritional Factors
    a. Mycotoxins e.g. ergot and aflatoxins. It is important for by-products such as sorghum wet distillers grains for raw grain to be screened for ergot. If present, ergot has the potential to be concentrated during the distillation process. This has been highlighted with aflatoxins in corn wet distillers grains in the United States.
    b. Tannins: e.g. the role of tannins on protein metabolism in wet sorghum distillers grains is still to be completely defined. Sometimes tannins can benefit protein metabolism by increasing rumen bypass, in other cases they can bind protein all the way through the digestive tract rendering it indigestible.

c. Gossypol: some cottonseed by-products may contain elevated levels of gossypol at certain times of the year which maybe an issue particularly for young or breeding classes of cattle.

7. By-product Response Curves: many dietary ingredients have defined quadratic response curves were performance (ADG and/or F:G is optimised). Once you exceed the biological optimal inclusion level, performance declines. The goal however, with by-product feeding is to find the economic optimal inclusion level where cost of gain is optimized and profit maximised. An example of biological response to corn wet distillers grains and solubles addition in dry rolled, steam flaked and high moisture corn-based diets is detailed below in Table 3. In these dry rolled corn diets, wet distillers grain and solubles (WDGS) has 120 to 150% the energy value of dry rolled corn and inclusion rates of 30 to 40% (DM basis) have been recommended. The value WDGS in steam-flaked corn based diets however, appears to be much less with small performance advantages up to 15% inclusion rates (DM basis), and negative influences on performance once this level is exceeded. Similar trials are needed with Sorghum Wet Distillers Grains with Solubles in Australia across a variety of grain sources and grain processing methods.

Table 2. Effect of Grain Processing and Corn WDGS level in corn-based diets

		WDGS Level, % DM				P-value	
Item		0	15	27.5	40	Linear	Quadratic
DRC							
	ADG, kg	1.65	1.71	1.76	1.78	<0.01	0.60
	G:F	0.163	0.170	0.181	0.185	<0.01	0.77
HMC							
	ADG, kg	1.67	1.80	1.80	1.75	0.15	0.04
	G:F	0.183	0.189	0.197	0.194	0.02	0.25
SFC							
	ADG, kg	1.66	1.70	1.63	1.56	<0.01	0.02
	G:F	0.182	0.186	0.182	0.183	0.91	0.40

*Corn processing x WDGS level interaction for ADG and G:F ($P < 0.01$)

Source: Corrigan et al. (2007) University of Nebraska, Lincoln

8. Marketing restrictions
   a. Chemical residues: by-products should not exceed MRL standards for animal feeding.
   b. BSE concerns: in recent years in Australia, some abattoirs have taken the ‘Precautionary Principle’ by not buying cattle from feedlots which feed tallow. Whilst feeding tallow is not illegal and no scientific link between feeding tallow and BSE has been demonstrated, these organisations have taken this stance for marketing reasons.

9. Processing costs.

10. Equipment and handling considerations.

Ultimately if a by-product is to be incorporated into a feeding program it must lower cost of gain and maximize annualized returns compared to conventional alternatives.

<u>Determining Energy Values of Ingredients</u>

So you are considering a particular by-product feed. A key factor is to determine the protein and energy content of the feedstuff. Sometimes ‘book values’ will not even exist for the by-product you are considering. Whilst protein values of feeds can be worked out by simple analytical chemistry techniques (e.g. LECO or Kjeldahl Nitrogen), determining energy values of by-product feeds in complete feedlot rations is much more complex.

There are four common ways of estimating energy values of by-product feeds:

1. *Chemical Composition:* A commonly used method is to submit a laboratory sample and obtained a proximate analysis derived ME value. An example of this would be to use the NRC (1984) equation:

$$DE\ (Mcal/kg) = 0.0504\ CP\% + 0.0770\ EE\% + 0.0200 CF\% + 0.000377\ NFE^2\% + 0.0110\ NFE\% - 0.152$$

Where DE = digestible energy, CP = Crude protein, EE = Ether Extract and NFE = Nitrogen Free Extract. All inputs into the equation are expressed on a dry matter basis.

Metabolisable energy is then calculated as 82% of the Digestible Energy Value (NRC, 1984). Whilst this method is relatively simple and may give a 'ballpark' indication of the feeds value, the accuracy and precision of these methods are questionable, particularly when trying to predict the response of a given by-product in a total mixed ration. Evaluation of 3 similar laboratory derived equations by Robinson et al. (2004) revealed poor accuracy and precision of prediction of in vivo metabolisable energy values.

Many other factors can influence the energy value of feeds other than the simple measures of CP, EE and NFE. Any factor that changes the digestible energy of feedstuffs has the potential to alter metabolisable energy content of feeds (e.g. level of intake, degree of ingredient processing, acid detergent insoluble protein, starch-protein matrices, amylose-amylopectin ratios in starch etc.). Grain processing for example dramatically changes energy values of grains. If we comparing steam flaked corn to dry rolled corn, their chemical composition on a dry matter basis may appear similar if we sample the processed grain correctly. Laboratory derived ME values will also appear similar even though actual net energy for gain values (e.g. 1.62 vs. 1.55 Mcal/kg) are markedly different due to starch gelatinization and disruption of the starch-protein matrix. Simple laboratory analysis also ignores associative effects between ingredients e.g. the response of Corn WDGS in steam-flaked corn vs. dry rolled corn diets mentioned above. The conversion efficiency of DE to ME is also influenced by factors such as dietary ionophore source and level, internal amino acid balance of the animal, level of intake, animal age and feed source (as these factors affect methane and urine energy losses).

2. *Calculating dietary net energy from performance data*: The most common way feedlot nutritionists obtain comparative energy data on ingredients is back calculating dietary net energy values through performance data (i.e. dry matter intake, shrunk weight gain, and body composition at a specified slaughter endpoint) utilising the California Net Energy Equations (NRC, 1996). By holding other dietary components fixed in energy value according to previously derived energy values, nutritionists back calculate dietary net energy values of the by-product.

To obtain an indication of a by-products value by this method requires correctly designed randomised scientific experiments. Adequate replication is required to generate statistical power (the ability to detect a treatment difference, when a real treatment difference exists). Similarly, graded titration of the by-product is needed. Much of the data we obtain on energy value of by-product feeds is obtained from US University trials using dry rolled or steam-flaked corn as grain sources. Whilst some relevance can be obtained from these trials, there is greater need for feed companies in Australia to fund research in Australian Feedlots where steam flaked barley, wheat and sorghum are the predominant grain sources. Associative effects between Australian by-products and these grain sources may differ.

3. *In Vivo Techniques:* generally these techniques are complex, costly, time consuming and limited to University research settings. Examples include direct and indirect calorimetry methods. Commonly in feedlot cattle nutrition changes in body composition and retained energy are determined (e.g.

comparative slaughter techniques, carcass specific gravity, urea dilution). Site and extent of digestion trials can also be conducted, the metabolisable energy content of diets estimated and dietary net energy calculated by fixed relationships detailed in the NRC (1996).

4. *In Vitro experiments:* in vitro measurements of digestibility by gas production and fermentation cultures may give some indication of diet digestibility and methane production. This area has potential in the future as a rapid analysis tool of potential by-product feeds.

Conclusions

Before feeding a byproduct it is recommended:

1. Do your homework!
2. Obtain professional advice on pricing the ingredient relative to other protein and/or energy sources.
3. Conduct daily oven dry matter analysis.
4. Conduct scheduled ingredient analysis.
5. Obtain a contract for specifications on dry matter and nutrients of interest.
6. If the product if it does not meet specifications reject the product or negotiate a price discount.

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