Containing Feed Cost Using Biofuel Coproducts

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▪ Introduction

2007 was one of the most difficult years for swine producers in western Canada. Grain prices were record high and feed remains the single, most important cost of hog production. North American governments have severely disrupted the global feed market supply and demand signals. Their mandate of ethanol inclusion in fuels and the provision of subsidies for the construction and operation of biofuel plants drove demand and grain prices to the extreme. The "*can't happen fast enough*" development of the biofuels industry is primarily driven by a quest to become less dependent on Middle East oil suppliers.

The consequential, rapid increase in the availability of coproducts of the ethanol and biodiesel industry, namely distiller's dried grain and solubles (DDGS) and canola press cake in western Canada, does not necessarily represent a low cost feed panacea for the livestock industry. Both biofuel co-products are high in dietary fibre and protein. Fibre utilization is poor in monogastric species and the hope of increased use by the mostly Alberta cattle industry will be constricted by its slow growth. Excess dietary protein contributed by these co-products could also mean greater nitrogen excretion and potentially greater harm to the environment. But widening biofuel co-product use to poultry and swine would broaden the market opportunity and address the urgent need to deal with the increasing oversupply.

This paper briefly summarizes some recent research findings and reviews some feeding strategies to optimize the inclusion and utilization of biofuel coproducts in Prairie hog diets.

▪ Energy Values of DDGS–the Greatest Challenge

Weight gain is the main determinant of facility utilization or barn place turnover. And dietary energy is what propels hogs and broilers to grow. Starch, mainly from grain, is the primary source of dietary energy in swine diets. Fat, either added (tallow, canola oil) or intrinsic to grain or from supplemental protein sources (soy meal, canola meal) is a second source of dietary energy. Excess protein can also serve as a third source of dietary energy, but the nitrogen must be first removed and eventually excreted. Dietary fibre, that is poorly utilized by monogastric animals, which don't produce themselves the proper enzymes to breakdown the main structural bonds, largely dilutes the dietary energy provided by starch, fat and degraded protein. The depletion of starch in grain resulting from its microbial conversion to ethanol and the expeller removal of oil from canola implies that both DDGS and canola press cake are high in fibre and protein.

The primary feed issue with DDGS is what "truly" its dietary energy value. The grain stock used to ferment has, by far, the greatest impact on the dietary energy value of DDGS. Ethanol processing in North America has been more common from corn than from wheat. Some of our local plants started processing corn - wheat mixes to get the process going, and then mostly or entirely switched to wheat. But as it happened in August 2006, with high priced wheat, some reverted to fermenting corn alone or wheat - corn mixes.

Fermenting wheat concentrates the fat content from approximately 2 to 5 - 6%. Fermenting corn concentrates the fat content from approximately 4 to 9 - 11%. Therefore, DDGS from a mix of these two grain stocks can have a fat content ranging from 4 to 12%. Because lipids provide the largest dietary energy per unit, such wide range in fat content in a DDGS grain mix, can complicate diet formulation and accurate prediction of animal growth.

Wheat has a somewhat higher fibre content than corn (3 vs. 2%). The fibre in wheat is also less digestible than the fibre in corn. If whole wheat is ground and fermented without removing the bran and blended with corn, the range of fibre digestibility in a DDGS mix of both grain stocks again becomes more variable.

Fermenting corn concentrates the protein from approximately 9 to 25 - 26%. Fermenting wheat concentrates the protein from approximately 13 to 32 - 38%. If a hog diet has higher crude protein because that's what has been least-cost formulated on using a DDGS mix, the nutritionist may not have a proper estimate of dietary energy. Moehn and Ball (2007) showed that each 1% extra protein in the diet decreased NE by 1% due to the energetic cost of excess nitrogen excretion.

Table 1 illustrates the nutritionist's conundrum regarding the range in dietary energy content of DDGS. The only manner in which a nutritionist can estimate the variation in nutrient provision in DDGS from constantly changing grain stocks is by conducting extensive lab testing (protein, fibre, fat, starch). Alternatively, he or she may rely on one supplier that is committed to using a single grain stock (e.g., Terra Grain Fuels, Regina). Ethanol producers are not likely to advise clients regarding the composition of their current grain stock mix. Perhaps CFIA could step in and enforce a description of the grain stock or mix in the labelling of DDGS.

Table 1. Apparent ileal and whole tract digestibility coefficients for gross energy and calculated DE and NE content of DDGS derived from wheat[1-5], corn[5] and triticale[5] (DM basis)

	Wht[1]	Wht[2]	Wht[3a]	Wht[3b]	Wht[4]	Wht[5]	Corn[5]	Triticale[5]
Ileal dig, %	65.6	47.3	-	-		62.9	60.5	68.2
Whole tract dig, %	77.4	66.6	59	74	71.8	78.8	71.6	72.1
DE, Mcal/kg	4.02	3.39	3.00	3.59	3.83	4.29	3.78	3.82
NE, Mcal/kg	2.38	-	1.78	2.22	2.42	2.74	2.46	2.49
Pig AA status	++	--	??	??	++	++	++	++

[1]Widyaratne and Zijlstra 2007
[2]Nyachoti et al. 2005
[3]Sauvant et al. 2004 (a < 7, b > 7% residual starch)
[4]Yañez et al 2007
[5]Zijlstra and Beltranena 2007

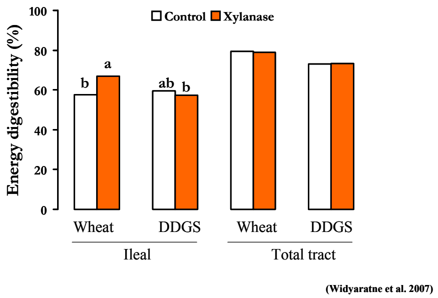
The only manner in which a nutritionist can predict animal growth when juggling such wide variation in ingredient nutrient provision is by utilizing the net energy system. He or she can then gain the advantage of the higher fat content while reducing the negative impact on performance of both high fibre and excess protein in DDGS.

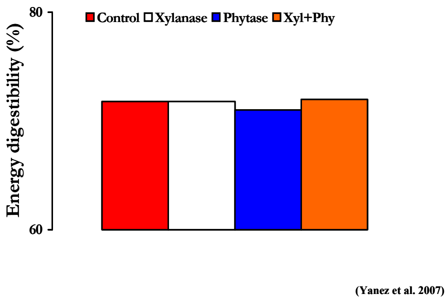
■ Fibre Digestibility of DDGS –Contribution to Energy

As introduced before, the extent of fibre digestibility in DDGS will depend on the grain stock fermented (e. g., corn, wheat, barley) and processing. Mechanical removal of the hull from barley or the bran from wheat prior to fermentation will reduce insoluble fibre content and consequently increase the energy value of DDGS. But the incognita is: To what extent does the microbial fermentation during ethanol production modify fibre digestibility for the pig? We have no answer to this question, but the proportion of solubles (stillage) added back to DDG during the drying most likely increases soluble fibre content and augments the variability in fibre digestibility.

If microbial fermentation makes more fibre soluble to the pig or its hindgut bacteria, can we further enhance its utilization by adding feed enzymes? Again, depending on the grain stock, addition of xylanase, cellulose and even protease feed enzymes to hog diets containing DDGS may enhance its fibre and protein digestibility. Unfortunately our preliminary results (Yañez et al. 2007) did not show that addition of xylanase to DDGS increased energy digestibility (**Figure 1**). However, we have not thoroughly tested xylanase addition yet nor the inclusion of multi-enzyme cocktails.

Figure 1. The effect of xylanase addition to wheat or wheat DDGS (left; Widyaratne and Zijlstra 2007) and the effect of xylanase, phytase or xylanase + phytase on the energy digestibility of wheat DDGS (right; Yañez et al. 2007)





▪ Amino Acid Availability of DDGS –Processing Effects

The high content of protein in DDGS is perceived as a main beneficial property of this ethanol co-product. Our low enthusiasm about this has more to do with the high protein content in the companion grains used in western Canadian hog diets than the protein content of DDGS per se. Due to the expected abundance of product, DDGS prices could be reduced so low that inclusion rates would be pushed as high as possible in hog diets.

If hog diets are formulated on the basis of total protein or amino acids, there will be a consequential increase in nitrogen excretion. Again, the net energy system is the only way nutritionists can discount the ingredient value due to excess protein and increased nitrogen excretion.

A second concern we have with DDGS is processing. Swine producers and the feed industry must understand what type of DDGS they are buying. Some plants will do wet milling and remove the wheat gluten prior to fermenting; thus reducing the protein content of their DDGS (e.g., Permolex, Red Deer). Other plants will establish contracts with grain growers to ferment a low-protein wheat (Andrew; e.g., Terra Grain Fuels, Regina) resulting in lower protein DDGS.

Major contributors to DDGS variability are the amount of concentrated solubles added back and the drying process. Processing plants prefer to add back as much solubles (stillage) as possible during the drying process; otherwise they have to sell another liquid, less uniform co-product. Adding back the solubles creates lumps when a viscous liquid comes in contact with the drying, mash distillers' grain. A way to dissolve the lumpiness of DDGS and prevent caking in storage bins thereafter is overdrying. However, the intensity of heat, the duration of heating, the speed of heating, and the equipment used for drying can cause amino acid (building blocks of protein) damage (i.e. reduced bioavailability). Protein damage generally becomes evident as the product becomes increasingly darker. However, improper fermentation and excess solubles added-back can also confer a dark colour to DDGS which will deepen with improper drying (scorching).

The best criterion we have to test for drying damage to protein is bioavailable lysine (**Table 2**). Lysine is the first limiting amino acid for swine and the one most likely to become heat-damaged. However, chemical testing for bioavailable lysine is expensive and not routinely conducted by local feed labs. The Hunter colour (L^*, b^*, a^*) is a fast method to gauge protein damage. Researchers at the University of Minnesota are working on optical density and fluorescence, which are more reliable method(s) to correlate with protein damage (Urriola et al. 2007). Near infrared spectroscopy (NIRS) is another rapid method that we are pursuing to evaluate DDGS quality (IFASA - Feed Quality and Supply Program). Commercial feed mills could monitor DDGS quality by rapidly scanning samples at receiving and adjusting their DDGS nutrient matrix accordingly.

Due to the variability in grain stock and processing, total protein and amino acid content range widely in DDGS, but probably not as much as its dietary energy value. Table 2 summarizes the amino acid content and our apparent ileal digestibility coefficients for a good wheat DDGS sample (Husky Energy, Lloydminster) and two poorer, darker samples of corn and triticale DDGS. These data proved that detailed chemical analyses plus animal digestibility work are key to understand coproduct variability.

Table 2. Total content (left) and apparent ileal amino acid digestibility coefficients (right) of corn, triticale and wheat DDGS as 30% replacement of a basal diet (85% wheat, 10% SBM) (Source - Zijlstra and Beltranena 2007

AA, %	89% DM Basal Diet	92% DM Corn DDGS	92% DM Triticale DDGS	92% DM Wheat DDGS	Basal Diet	Corn DDGS	Triticale DDGS	Wheat DDGS
Arg	0.96	1.09	1.15	1.41	82.3	78.6	83.0	91.9
His	0.43	0.59	0.61	0.73	81.7	64.5	73.1	86.5
Iso	0.68	1.01	1.03	1.21	78.3	66.9	75.0	88.7
Leu	1.26	2.34	2.39	2.54	80.3	80.1	85.5	94.8
Lys	0.69	0.61	0.69	0.96	67.8	46.0	50.2	71.3
Avail. Lys	-	0.41	0.53	0.88	-	0.19	0.27	0.63
Met	0.27	0.44	0.48	0.52	80.4	74.0	81.1	92.0
Cys	0.32	0.49	0.49	0.59	76.0	59.8	63.7	88.0
Phe	0.87	1.36	1.36	1.71	81.6	80.4	85.9	93.4
Tyr	0.49	0.91	0.94	1.28	78.8	81.3	88.8	95.9
Thr	0.57	0.93	0.92	1.06	72.6	66.1	70.6	83.1
Try	0.22	0.15	0.17	0.25	79.6	69.4	72.4	84.2
Val	0.79	1.18	1.22	1.38	76.1	67.1	74.4	89.1
AAProt[a]	17.5	22.6	23.2	28.5	78.9	69.6	75.1	87.8
Crude Protein[a]	18.4	26.3	26.9	32.6	83.5	65.5	66.5	84.2

[a]Crude protein reflects total nitrogen. AA Prot reflects nitrogen contained within amino acids

▪ Phosphorus in DDGS –Enhancing Its Availability

Phosphorus content concentrates two to three times in DDGS with respect to the parent grain stock. Microbes (primarily yeast) and the ethanol production process itself increase mineral availability somewhat. And although damaging to protein quality, overheating at drying also increases phosphorus availability (Batal 2006). Thus, the larger the inclusion level of DDGS in the diet, the lower the consequential need to supply phosphorus from inorganic sources (e.g., mono/dicalcium phosphate), resulting in feed cost savings.

We have also tested if feed phytase enzyme can further increase phosphorus availability from wheat DDGS. Our preliminary results showed a positive response to phytase addition in a semi-purified diet (Yañez et al. 2007).

■ Feeding DDGS –High Levels of Inclusion

Assuming that the cost is low, one has confidence in the nutrient matrix of DDGS, and has considered the concerns described above, how high can one push the inclusion of DDGS in hog diets? Two additional concerns arise at high feed inclusions: one is palatability and voluntary feed intake; the other is the effect on carcass and pork quality.

Local results suggest that good quality corn DDGS can be included in hog diets up to 25% of the diet without negative effects on feed intake (**Table 3**).

Table 3. Effect of feeding increasing levels of corn DDGS on hog performance in a commercial facility in Alberta (Source - Gowans et al. 2007)

	Corn DDGS, %							*P* <
Item	**0**	**5**	**10**	**15**	**20**	**25**	**SED**	**Linear**
Day 0 to 25								
ADG, kg/d	0.942	0.977	0.961	0.951	0.963	0.947	0.015	0.77
ADFI, kg/d	2.02	2.10	2.06	2.01	2.05	2.02	0.033	0.31
F:G	2.15	2.15	2.15	2.11	2.13	2.13	0.027	0.32
Day 25 to 53								
ADG, kg/d	0.931^{a}	0.974^{b}	0.966^{b}	0.963^{ab}	0.981^{b}	0.987^{b}	0.017	0.01
ADFI, kg/d	2.63	2.71	2.63	2.55	2.68	2.59	0.041	0.15
F:G	2.83^{a}	2.78^{ab}	2.73^{bc}	2.64^{cd}	2.74^{b}	2.63^{d}	0.043	0.01
Day 0 to 53								
ADG, kg/d	0.936^{a}	0.975^{b}	0.964^{b}	0.958^{ab}	0.972^{b}	0.967^{b}	0.012	0.05
ADFI, kg/d	2.33	2.41	2.36	2.29	2.38	2.31	0.029	0.12
F:G	2.49^{a}	2.47^{a}	2.45^{a}	2.39^{b}	2.45^{a}	2.39^{b}	0.026	0.01
Feed cost, $/kg gain[e]	0.405	0.405	0.405	0.399	0.413	0.411	0.004	0.08
IOFC, $/pig[f]	39.4	40.7	40.4	40.5	40.2	40.1	0.64	0.58

[a,b,c,d]Means with different superscript letter differ (*P* < 0.05); Average of 8 pens per DDGS level.
[e]Wheat $105, soybean meal $270, peas $130, Canola $120, corn DDGS $123, tallow $470 per tonne
[f]Income over feed cost. Pig price = $1.3 kg dressed

Nonetheless, trial data evaluating the effect of high levels of wheat DDGS inclusion on feed intake and performance were not publicly available at writing. But the practical dietary inclusion levels of wheat DDGS in Prairie hog diets is likely to be lower compared to the high inclusion levels of corn DDGS in American corn-based diets. With our high protein Prairie grains in contrast to corn, it doesn't take much for excess protein to constrain wheat DDGS inclusion levels.

▪ DDGS –Effects on Carcass and Pork Quality

Assuming no detrimental effect on feed intake, the next concern with high inclusions of DDGS is the effect on carcass and pork quality. Feeding DDGS resulted in a marginal decrease in carcass dressing percent (Thacker 2006). As per barley-based diets, the gut compensates to handle the higher fibre content of DDGS in comparison to soybean meal - wheat diets. The thicker, heavier gut becomes a larger proportion of the live animal. Unless market weight of pigs is increased marginally (e. g. ~2 kg), removal of the gut at evisceration will result in a lighter warm carcass weight.

Regarding pork quality, high corn DDGS inclusions are a greater concern than high wheat DDGS inclusions would be because corn DDGS contains nearly twice the fat content. As per the Alberta study of Gowans et al. (2007), increasing levels of corn DDGS up to 25% did not increase backfat thickness at the grading site. Furthermore, the type of fat in corn DDGS is unsaturated, like in canola press cake.

Feeding unsaturated fats to hogs is known to cause soft or “fluffy” bellies. Bacon slabs don’t slide well and bacon strips tend to stick together at cooking. The taste and texture of lean pork become oily and mushy at chewing. Sausage quality is compromised, increasing the oily sweat off and reducing wiener firmness.

The Danish Meat Research Institute uses an iodine value (ratio of unsaturated:saturated fatty acids) of 70 as the maximum tolerable for pork fat quality. Shurson 2006 reached 70.6 and 72.0 in hogs by feeding 20 and 30% corn DDGS, respectively (www.ddgs.umn.edu/).

Not much American pork quality information is publicly available for higher inclusion rates of corn DDGS (www.ddgs.umn.edu/). It is possible, therefore, that the packer may be unaware of the detrimental impact of high corn DDGS inclusions on pork quality until pork processing.

Feeding decreasing levels of DDGS as hogs approach market weight is a strategy that should reduce feed cost and mitigate the negative effects on pork quality. We have proposed such study including detailed pork quality work to be conducted at AAFC Lacombe Research Centre in 2008.

Low cost DDGS and eventually canola press cake should be a flag to packers to more closely monitor pork quality. With the new requirements of country of origin label (COOL), it will be easier for consumers to associate a country with mushy, oily pork.

▪ Canola Press Cake –Feeding Considerations

Almost no research results are available yet for feeding canola press cake. It is an even more novel biofuel coproduct in comparison to DDGS. However, much can be inferred from previous Canadian research on feeding full-fat canola seed and solvent-extracted canola meal. We are currently establishing nutrient digestibility coefficients for a commercially available product.

The main issue with this co-product will be the variability in residual oil content after pressing. If the co-product originates locally from farmers making biodiesel, the residual oil content should be higher than if produced commercially (e. g., approximately 12% fat). Therefore, fat analysis should be requested in addition to protein and moisture content at testing.

If cost were low, as per the DDGS trend, the two main issues restricting canola press cake inclusion rates in hog diets would be palatability (feed intake) and the effect on carcass and pork quality discussed before.

Glycerol is a co-product of biodiesel production. Glycerol is primarily used in the manufacturing of soaps, but can also be fed to livestock. At 10% inclusion rate, it resulted in similar growout performance to hogs fed a corn-soybean meal diet. At 20% inclusion, it caused flow problems with mash feed (http://cabiblog.typepad.com/hand_picked/2007/05/glycerol_a_bypr.html). Lammers and coworkers (2007) concluded that glycerol is a highly digestible source of energy for nursery pigs and hogs because the digestible energy value was not different from the gross energy value of crude glycerol.

▪ Conclusions

We view the feeding of biofuel co-products as the way of the future as we enhance the food, feed and bioindustrial multi-use of raw agricultural commodities.

The issues surrounding the nutrient variability of DDGS are a barrier to reliably predicting animal performance. Knowing the main grain stock, some processing details, adopting rapid scanning (NIRS) technology and formulating hog diets using the net energy system, should go a long way to containing feed cost for hog producers. But as the availability increases and co-product cost decreases, pork quality -if not voluntary feed intake first-, may be what will ultimately determine the highest levels of dietary inclusion of biofuel co-products.

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