BYPRODUCT FEED INGREDIENTS FOR SWINE DIETS - OPPORTUNITIES AND CHALLENGES

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INTRODUCTION

High commodity prices coupled with low pork prices have made it necessary for pork producers to consider their options for reducing feed costs. The biofuel industry has created new markets and competition for grain commodities containing starch and sugar for ethanol production as well as commodities with oils and fat for biodiesel production, contributing to volatile but generally stronger grain commodity prices. This situation is not unique to North America and is prompting producers globally to focus less on maximizing production and more on minimizing feed costs. Various byproducts from grain and food processing can be potentially cost effective alternatives as a partial substitute for the more traditional nutrient dense commodities such as corn, wheat and soybean meal. There are those that would suggest utilizing byproduct ingredients is the direction that the livestock industry should be or will be heading anyway and that the future of the livestock industry will depend on the animals' ability to make use of alternative feed resources that are unusable by people. In a recent Feed Management magazine article, Dr. Pearse Lyons, founder and president of Alltech, predicted that "in five to ten years from now, very little maize will be used in animal production. What will become more common will be fibre feeds, those containing a higher level of cellulose. There will be more protein sources as well as fibre and less starch and fats."

This presentation will discuss the process for selecting byproducts, mainly from an energy replacement strategy perspective, some considerations about fibre, a potential limiting factor in byproducts, and a look at some of the byproducts based mainly on available supply here in the Ontario market, with a particular emphasize on distillers dried grains with solubles from corn based ethanol production.

BYPRODUCT SELECTION

Replacing nutrient dense feed ingredients in pig diets with byproduct feed ingredients is not a straightforward process. The biofuel industry and other grain and oilseed processors generate a number of different byproducts. However the concentration of the residual components in these byproducts is quite different than their parent commodity such as corn, wheat or soybeans. As a result, many of them cannot be considered a one-to-one replacement for commodities such as corn or wheat in swine diets. Their nutrient concentrations and other limiting factors can, in some cases, make a nutrient replacement strategy a little like fitting a square peg into a round hole. In order to facilitate this process, it is very important that we understand the nutritive value of byproducts, the risks and potential extra costs associated with their use and of course, the potential economic benefits when properly formulated into pig diets.

Often the selection and purchase decision making process of alternative feeds involves a combination of subjective as well as objective evaluations, with the subjective based slightly more on perception and the objective based more on factual information.

Subjective Evaluation

- Price per tonne or unit - a good place to start.
- Quality assessment – appearance, moisture content, smell, colour, taste.
- Limiting factors - particle size, flowability, bulk density, storage, transportation.
- Consistency - uniformity composition, supply.

Objective Evaluation

- Value/cost effectiveness – considers potential performance, prediction models.
- Nutrient content - proximate analysis, SID, NE, and available phosphorus levels.
- Inclusion rate - projected performance, limiting factors, anti nutritional factors.
- Availability - ingredient available on a local, continuous basis.

Tables 1 and 2, while not providing all the necessary information for diet formulation, can be useful in the decision making process.

FIBRE CONTENT CONSIDERATIONS

Several byproduct ingredients are partially made up of the residual seed coats or bran of the parent commodity and therefore contain levels of fibre that are two to three times higher than their parent, as shown in Table 3. Such byproducts are referred to as fibrous byproducts or fibrous feeds, although there is no official definition. Fibrous feeds traditionally have not been widely utilized in pig weaning, growing and finishing diets due to the well documented negative impacts of performances because of lower protein and energy digestibility and lower nutrient density. Fibre has been considered a limiting factor for inclusion in diets. However, not all fibre is created equally and differences in fibre digestibility do exist and are due to many factors, including the type and amount of fibre in the feed, as well as pig size.

It is known that sows have greater capacity to extract energy from fibrous feedstuffs compared with growing pigs (Noblet & Le Goff, 2001), as shown in Table 4.

Table 1. Feeding value of energy feeds compared to corn.

Feedstuff	Relative value compared to corn, %
Corn	100
Alfalfa meal, dehydrated	65 to 75
Barley	90 to 95
Dried distillers grains	75 to 112
High lysine corn	110 to 115
High oil corn	110 to 115
Nutridense corn	110 to 115
Millet	90 to 95
Milo	96
Oats	70 to 80
Oat groats	110 to 115
Rye	80 to 85
Fat and oil	210 to 220
Soy hulls	60 to 65
Triticale	95 to 105
Wheat	105 to 107
Wheat middlings	90 to 95
Whey, dried	100 to 110

Adapted from the NPPC Feed Purchasing Manual, Nebraska and South Dakota Swine Nutrition Guide, and Swine Nutrition Guide from the Prairie Swine Centre.

Table 2. Typical maximum usage rates for common energy sources.

Ingredient	Maximum recommended percent of complete diet* Starter	Grow-finish	Gestation	Lactation	Limitation
Alfalfa meal, dehy	0	10	25	0	High fiber
Bakery waste, dehy	25	*	*	*	High salt
Barley	25	*	*	25	High fiber
Beet pulp	0	5	50	0	High fiber
Corn	*	*	*	*	None
DDGS	5	10	20	5	Amino acid balance and palatability
Corn gluten feed	5	10	*	5	High fiber
Corn, hominy feed	0	60	60	60	Amino acid balance
Fat/oils	8	5	5	5	Feed handling
Millet	10	40	40	10	Difficult processing
Molasses	0	5	10	5	Low energy
Oats	5	20	50	0	High fiber
Oats groats	+	+	+	+	None
Rye**	0	25	25	10	Variability
Sorghum (milo)	+	+	+	+	None
Soy hulls	0	10	20	0	Fiber and bulk density
Triticale**	10	+	+	50	Variability
Wheat bran	0	10	30	10	High fiber
Wheat, hard	+	+	+	+	None
Wheat middlings	5	25	+	5	High fiber
Wheat shorts	10	40	40	40	Variability
Whey, dried	40	15	5	5	High lactose

Adapted from the NPPC Feed Purchasing Manual, Nebraska and South Dakota Swine Nutrition Guide, and Swine Nutrition Guide from the Prairie Swine Centre.

* Percentages suggest maximum allowable inclusion rates for energy sources. Economics and pig performance standards must be considered for actual inclusion rates. Most or all of the nutritional limitations can be overcome with proper formulation.

** Must be free of ergot.

+ Denotes no nutritional limitation in a diet balanced for essential amino acids, energy, minerals, and vitamins.

Table 3. **Fiber concentration (DM basis) in corn, soybean meal, and other fibrous feedstuffs fed to livestock.**

Feed Ingredient	CF,%	NDF,%	ADF,%	TDF,%	SDF,%	IDF,%
Corn	2.6	9.0	3.0	6.4	1.7	4.7
SBM, 44% CP	7.0	13.3	9.4	33.1	1.6	31.5
SBM, 47% CP	3.0	8.9	5.4	27.6	1.4	26.2
Alfalfa	26.2	45.0	35.0	56.7	4.2	52.4
Oat bran	-	19.2	-	15.8	7.5	8.3
DDGS	9.9	44.0	18.0	42.9	0.7	42.2
Oat Straw	40.5	70.0	47.0	76.6	2.2	74.4
Soybean Hulls	40.1	67.0	50.0	83.9	8.4	75.5
Wheat Straw	41.6	85.0	54.0	71.5	0.5	71.0
Corn Stalk	34.4	67.0	39.0	77.3	2.9	74.4
Sugar Beet Pulp	19.8	54.0	33.0	65.6	11.7	53.9
Potato Pulp	-	-	-	33.3	11.0	22.3

Sources: NRC (1998); NRC (1988); Dale (1998); and Univ. of Minnesota laboratory analysis.
CF = crude fiber, NDF = neutral detergent fiber, ADF = acid detergent fiber, TDF = total dietary fiber, SDF = soluble dietary fiber, SBM = soybean meal, and DDGS = dry distillers grains with solubles.

Table 4. **Comparative digestibility from growing pigs and sows.**

	Mean of 72 Diets[1]		Mean of 14 Diets[2]	
	Growing Pigs	**Sows**	**Growing Pigs**	**Sows**
Digestibility, %				
Crude Protein	50	60	75	85
Crude Fat or EE	38	42	55	69
Fibre	49	55	38	64
ME (MJ/kg DM)	12.23	13.15	13.49	14.43

EE, ether extracts; ME, metabolisable energy.
[1]Data from Fernandez et al. (1986) and Jorgensen et al. (unpublished).
[2]Data from Noblet and Shi (1993).

The most widely accepted definition of fibre is the sum of non starch polysaccharides plus lignin. It is the proportion of the feed that is not digested by endogenous secretions of the digestive system, but are broken down to a variable extent by microbial fermentation largely in the large intestine (Knudson, 2008).

This chart may help to better understand fibre, but it also serves to demonstrate the complexity of fibre. The effect of fibre inclusion in swine diets has received considerable attention and research, but many aspects of fibre in swine diets remain somewhat controversial.

Fiber Analysis			
Crude fiber	NDF, ADF	Enzymatic – chemical	
Cellulose Lignin Hemicelluloses	Hemicelluloses Cellulose Lignin	Total NSP Souble NSP Insoluble NSP Low molecular weight sugars Monomers	Cellulose Pectins β-glucans Pentosans Xylans etc.

In theory, the performance of pigs fed dietary fibre will not decline if one formulates diets in such a way that pigs consume adequate amounts of net energy, ileal digestible amino acids and other essential nutrients (Johnston et al., 2003). Both the digestible energy (DE) and the metabolizable energy system (ME) are used currently in swine nutrition, but the net energy (NE) system is seen by many as the superior system to more precisely formulate diets that include fibrous byproduct feeds in particular. The net energy system reflects the energy the pig will actually utilize. For ingredients that have a higher protein content and for ingredients that have high fibre content, it's much more effective to utilize net energy (NE) as a system for formulating the diets because both the DE and the ME systems tend to over-value ingredients that have high fibre and high protein, in addition to undervaluing fat (Dr. Martin Nyachoti, 2009).

Increasing attention has been paid in the past decade to dietary fibre in swine nutrition due to its multiple functionalities as well. Dietary fibre is considered as a possible means to reduce nitrogen losses (reduce ammonia emission) of production units, to improve pig intestinal health and animal welfare, in addition to reducing feed costs.

BYPRODUCT OPTIONS FOR ONTARIO SWINE PRODUCERS

Distillers Dried Grains with Solubles

- Considered a good source of amino acids, energy and phosphorus suitable for inclusion in swine diets at all phases of production.
- A cost effective alternative feed – become more widely used in Ontario pork production – potential to save $3 to $9 per market hog for each 10% added (Shurson, 2009).
- Ontario currently has 6 corn based ethanol production units in operation with 4 of these plants supplying approximately 560,000 dry tonne equivalents of DDGS to the market (some of this tonnage also sold as wet distiller or condensed distiller's solubles). In addition, some DDGS are being imported from the USA.
- Considerable DDGS/swine nutritional research has been conducted in the last ten years in North America.

- Swine researchers, Dr. Hans Stein at the University of Illinois and Dr. Gerry Shurson at the University of Minnesota, summarized the research from North America that was published prior to 2008. (H.H. Stein & G.C. Shurson, 2009) – a great reference document for the swine industry!
- The following are points from their summary;
    - Average DE and ME similar to corn, NE approx. 86% of corn NE.
    - Phosphorus in DDGS is highly digestible for pigs, with an apparent total tract digestibility of 60% reported.
    - The concentration of most amino acids (AAs) are 3X greater than corn, but the standard ileal digestibility of most AAs is approximately 10 % less than in corn.
    - The total dietary fibre levels in DDGS are approximately 3X greater than those in corn.
    - The apparent total tract digestibility of dietary fibre is less than 50%, which results in reduced digestibility values for DM and NE values for DDGS.
    - The report concluded that research on practical ways to enhance DM and energy digestibility, specifically by improving the digestibility of insoluble fiber fraction, could improve the feeding value of DDGS.
    - Table 5 summarizes their recommended inclusion rates for DDGS in swine diets.

Table 5. Inclusion rates of DDGS.

Item	Recommend	Maximum
Gestation	50 %	50%
Lactation	30%	40%
Nursery, 1+2	0	20%
Nursery, 3+4	30%	30%
Grow-Finish	30%	45%
Late Finish	20%	30%

- Fat quality in pork from pigs fed DDGS has been a concern. Adequately firm fat should have an iodine number below 70-74. Hogs fed at 20% level had around a 67 reading, whereas 30% level raised it to 73. By removing DDGS from the finishing diet, with a 30% inclusion for the last 2 weeks, the iodine number lowered to 67 (Beltranena et al., 2009).
- Lysine is suggested to be most variable in digestibility, which is believed to be in large part due to heat damage.
- Colour is often used to subjectively assess quality, with dark coloured DDGS presumed to have less amino acid digestibility than the golden coloured DDGS.
- Current and past research projects at the University of Guelph (Ridgetown College) are looking at the potential effects of colour of DDGS on pig performance and the possibilities of colour as an objective tool for assessing DDGS quality.
- Tables 6 and 7 summarize the pig performance from a feeding trial where levels of 10% and 20% DDGS are used at the Ridgetown campus of the University of Guelph and the data collected from six plants both in Ontario and in close proximity to Ontario as part of a research project looking at variability, as well as colour as an indicator of DDGS digestibility.

Table 6. Effects of dietary treatment on pig growth rate, feed intake and carcass quality.

	Control diet	10% DDGS + Lysine	20% DDGS + Lysine	10% DDGS No Lysine
Growth Performance				
Number of pigs	24	21	23	16
Days to market (by pen)	56.6	56.7	55.2	56.6
Average daily gain, kg	1.13	1.12	1.14	1.09
Feed Intake Measurements				
Total feed intake, kg	174.7	170.6	171.3	170.9
Average feed intake, kg/d	3.11	2.99	3.11	2.96
Feed efficiency (F/G)	2.80	2.73	2.73	2.63
Cost of gain ($/kg) – 2005	0.50	0.47	0.46	0.45
Carcass Measurements				
Dressing percentage	79.6	79.8	79.4	79.5
Yield index, %	61.3	61.1	60.5	60.8
Grade fat, mm	17.1[a]	17.8[ab]	19.3[b]	18.5[ab]
Meat depth, mm	62.0	62.6	61.3	64.0

McEwan et al. (University of Guelph)
[ab] LS within row that do not share a common superscript differ significantly (P<0.05).

Bakery Byproduct

- Composed of many types and proportions of bakery products.
- Energy levels similar to corn can be higher depending on their composition and their sugar and fat levels in particular.
- Less than 2% crude fibre levels.
- Great ingredient for all phases of pig production.
- Relatively small particle size.
- Prices can be high due to competition from other non ruminant nutritional markets.
- Cautions - they can have relatively high sodium levels; flowability challenges because of the fat content and small particle size and their makeup can be quite variable.

Table 7. DDGS nutrient content and availability for six participating ethanol plants.

	A	B	C	D	E	F
Nutrient Content (% as fed)						
Dry matter	87.4^{b}	88.2^{bc}	88.5^{c}	87.6^{b}	88.1^{bc}	86.3^{a}
Crude protein	26.8^{bc}	28.9^{d}	25.3^{a}	25.2^{a}	27.3^{c}	26.1^{ab}
NDF	29.7^{a}	29.2^{a}	33.8^{c}	33.6^{c}	30.9^{ab}	32.4^{bc}
Fat	9.6^{a}	10.6^{b}	10.1^{ab}	10.1^{ab}	9.7^{a}	9.9^{ab}
Starch	2.2	3.1	3.5	2.5	3.7	2.5
Phosphorus	0.77^{ab}	0.74^{a}	0.76^{ab}	0.79^{b}	0.78^{ab}	0.85^{c}
Sulphur	0.44^{a}	0.84^{c}	0.47^{a}	0.47^{a}	0.65^{b}	0.58^{b}
In vitro Nutrient Digestibility (%)						
Dry matter	62.2^{b}	67.4^{c}	59.5^{a}	61.4^{ab}	61.4^{ab}	62.6^{b}
Crude protein	80.9^{b}	86.1^{c}	80.7^{b}	77.9^{a}	80.1^{b}	79.9^{b}
Colour Evaluation (CIE, L* a* b* scale) for Unground Samples						
Colour L*	55.4^{bc}	50.2^{a}	57.8^{cd}	59.3^{d}	53.8^{b}	59.3^{d}
a *	10.7^{c}	11.0^{c}	9.2^{ab}	8.9^{a}	9.7^{b}	9.2^{ab}
b *	48.4^{d}	39.9^{a}	46.2^{bc}	50.0^{d}	44.6^{b}	48.2^{cd}

McEwan et al. (University of Guelph)
[abcd] LS means within row that do not share a common superscript differe significantly ($P < 0.05$).
L* = lightness of colour (0 = black, 100 = white). Higher values for a* and b* are indicative of increased redness and yellowness, respectively.

Corn Gluten Feed

- Fibrous byproduct of wet corn milling - consists of the corn bran, some corn germ and steep water.
- Traditionally, because of its fibre content and lack of palatability, it was not considered a good alternative feed for swine.
- Good supply in Ontario –CASCO plants in London, Cardinal or Port Colborne and Collingwood Ethanol (only wet byproducts from Collingwood plant).
- Cardinal plant currently pellets some of their gluten feed.
- Research would suggest when fed to gestating sows at high levels (around 90%) the energy value is 70 to 80% of the net energy of corn (Honeymann).
- Has low level of fat (3%) compared to DDGS but higher level of residual starch (12-15%).
- Fibre in CGF may be more readily digested due to the fact it has undergone the wet milling process and can meet all the energy needs of gestating sows (Honeyman).
- Yen and al. showed pigs performed well when corn gluten feed was included as part of the diet up to 30%, replacing corn and soybean - pigs ranged in starting weight from 23 kg up to 55kg.
- Yen and al. - determined that supplemental Tryptophan was beneficial as well as pelleting.
- NE value for sows need to be determined.
- A byproduct whose feed value could be enhanced by processing (e.g. pelleting as well as enzyme specific to gluten feed).

Wheat Shorts

- Wheat shorts are the layer of the wheat kernel just inside the outer bran layer covering the endosperm and usually contain 5 to 10% crude fiber and 15 to 20% crude protein (good source of lysine and threonine).
- Energy wise, on a NE basis, are approximately 85-88% of the value of corn.
- 10% inclusion for starter pigs and 40% for grower/finisher and sows. Can support good performance in properly balanced diets.
- Make a good ingredient in pelleted feed products and pelleting can potentially improve the value of the shorts.

Soybean Hulls

- Soybean hulls - separated from the soybean during the solvent oil extraction process.
- Potentially beneficial and cost effective as a source of fiber (56.4% NDF), protein (12.0%) and energy (NE 1003 kcal/kg), particularly in sow diets.
- Despite high fibre level, they have low levels of lignin.
- Can help reduce ammonia levels in barns.
- Inclusion at around 5% in grower finishing diets.
- Low bulk density- can affect feeding systems and storage; most soyhulls are sold in a pelleted form.
- Potential improvement in digestibility with future technologies - e.g. enzymes or processing.

SUMMARY

Byproduct feed ingredients such as DDGS can be used as cost effective partial replacements for higher priced commodities traditionally used in nutrient dense swine diets. Pig performance may not be affected if inclusion is based on researched inclusion rates and using effective net energy diet formulation, standardized ileal digestibley amino acids and digestible phosphorus. Inclusion rates beyond this may save feed costs but may have a negative effect on pig performance. In those situations, the cost versus benefit in the whole production system will need to be considered. The future use and effectiveness of byproduct ingredients and, in particular, ones considered to be fibrous, will depend upon effective supplemental enzymes, practical and timely feed quality evaluation technology, innovative processing technologies, vendor assurances and possibly genotype selection.

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