Further Processing for Better Utilization of Co-products in Monogastrics

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Abstract

Canola meal and DDGS are common co-products widely available in North America. Processing of ethanol feedstocks and oilseeds results in co-products characterized by both high protein and high fibre content. Dietary fibre can act both as an impairment to nutrient digestibility and also as a diluent. Efforts into processing of co-products for monogastrics, therefore, have been aimed at reducing one or both of these antinutritional effects of dietary fibre. We have observed improvements in amino acid digestibility of corn, wheat and triticale DDGS using extrusion technology. Our data however suggest that this improvement may be determined by the level of solubles in the DDGS. There is little data available regarding effects of extrusion on feed value of canola meal. Enzyme supplementation to improve feeding value of co-products has also been extensively studied. The literature suggests that enzyme supplementation of diets cannot be justified solely on improvements in co-product nutrient digestibility at practical inclusion levels. Our group has had relatively good success using a couple of different techniques to create DDGS and canola meal fractions with higher nutrient densities. Digestibility and growth performance studies with broilers and pigs confirm that these fractions can result in increased performance. Further research, however, is required to optimize parameters to permit commercial scale fractionation. Continued efforts to find feasible technologies to enhance feed value of co-products will permit their use to be increased in monogastric feeds.

Introduction

Co-products have long been recognized as cost-competitive feedstuffs for monogastric species. Recent spikes in prices of key North American feed grains along with increasing availability of co-products is leading to heightened interest into ways that they could be used more effectively to reduce feed costs.

Canola production and crushing in Western Canada has increased markedly over the past 35 years (**Figure 1**). A recent report attributed nearly $15 billion of direct and spin-off economic activity in Western Canada to canola production. The Canadian canola industry was estimated to have generated over 4 million Tonnes of canola meal in 2012, about 80% of which was exported, primarily to the US dairy industry (Statistics Canada, 2013).

Production of distillers dried grain with solubles has also increased dramatically over the past 2 decades, but has stabilized over the past 3-4 years (**Figure 2**). The USDA projects an increase in DDGS production of only about 10% over the next decade (Hoffman and Baker, 2010). Much of the DDGS produced in North America is corn-based and is produced in the corn belt of US. In 2012, about 40% of the US corn crop was used for ethanol production. While the vast majority of corn DDGS is fed domestically to dairy and beef cattle, DDGS is a common component in US swine and dairy rations, displacing both corn and soybean meal in diet formulations.

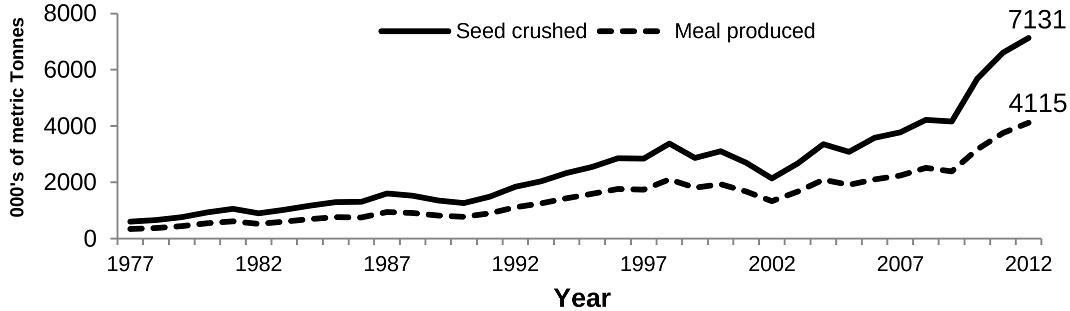

Figure 1. Canola seed crush and canola meal tonnage produced in Canada, 1977-2013 (adapted from Statistics Canada, 2013).

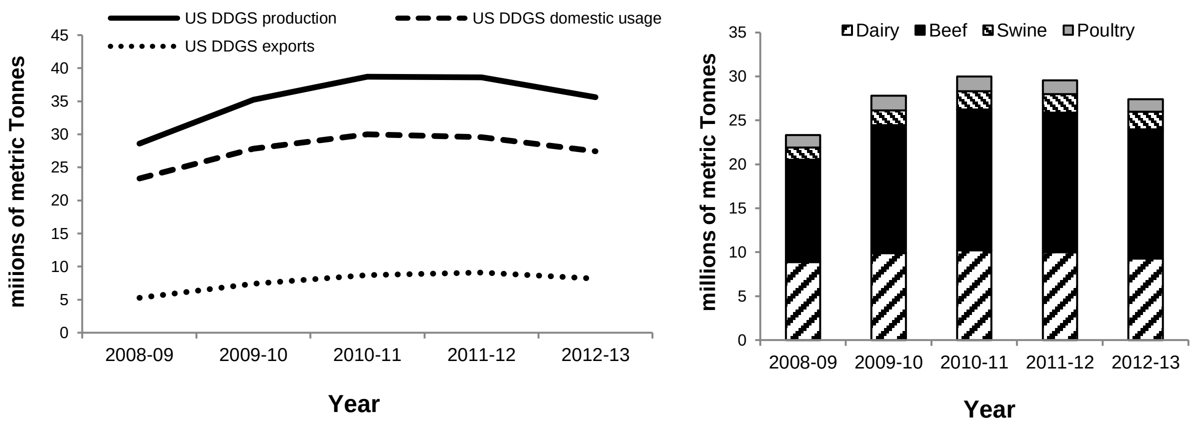

Figure 2. Corn distillers dried grains with solubles production and domestic usage by livestock commodity in the US, 2008-2013.

Both the oil extraction and ethanol production systems result in the concentration of protein, fat (in the case of corn DDGS), minerals and fibre in their respective co-products. For monogastrics, high fibre content is problematic for two reasons. At a minimum, fibre acts as a diluent - reducing the concentration of digestible energy and nutrients, in particular amino acids. Depending on the type, fibre in feedstuffs can also impair nutrient digestibility, either through altering gut passage rates or by impeding access of digestive enzymes to their substrates. A major issue limiting co-product inclusion levels in pig and poultry diets is their dietary energy concentration. Increasing the dietary energy density in co-products would therefore have a direct impact on use in monogastric feed applications. This in turn would create opportunities for producers to reduce feed costs and increase competitiveness.

For almost as long as these products have been widely available, researchers have been looking for ways to improve their feed value for monogastric species. This article will focus on investigations into 3 processing techniques and technologies intended to enhance the feed value of canola meal and DDGS for monogastrics:

1. Extrusion
2. Exogenous enzyme supplementation

3. Fractionation

Extrusion

The verb 'to extrude' is a combination of the Latin words '*ex*' (out) and '*trudere*' (to thrust), which is an apt description of what occurs to a substrate during extrusion processing. Extruders, in essence, consist of a screw shaft that moves a substrate along a barrel, eventually forcing it through a restricted opening. During passage through the extruder a combination of pressure/heat and shear forces act on the substrate to alter its physiochemical properties.

Extrusion is considered a form of low-moisture cooking and depending on the production conditions can either enhance or reduce the quality of a feedstuff (**Table 1**). For a more detailed discussion of extrusion and physiochemical changes in feedstuffs, the reader is directed to the review by Singh et al. (2007) or the book edited by Riaz (2000).

Table 1. Summarized effects of extrusion processing on of nutrients and constituents of feeds (based on Singh et al., 2007).

Nutrient/constituent	**Effects of extrusion**
Protein/amino acids	▪ General increase in protein digestibility due to protein denaturation ▪ Maillard reaction between lysine and reducing sugars can reduce lysine availability (moreso under high barrel temperatures and low moisture conditions) ▪ High asparagine content in extruded substrate can result in formation of acrylamides (carcinogens)
Carbohydrates	▪ Gelatinization of starch (at much lower moisture levels than other cooking techniques) ▪ Release of glucose units from starch ▪ Loss of sugars due to participation in Maillard reactions ▪ Destruction of oligosaccharides ▪ Reduction in molecular weight of pectins and hemicellulose ▪ Conversion of insoluble dietary fibre to soluble dietary fibre
Lipids	▪ Increases extractability of lipids through increased disruption of cell walls ▪ Minimizes lipid oxidation through destroying enzyme activity responsible
Minerals	▪ Increases availability of several key minerals through partial destruction of phytate
Anti-nutritional factors	▪ Inactivation anti-nutritional factors including trypsin inhibitors, lectins and tannins

Extruders generally consist of either single screw or twin-screw designs. Due to initial capital expense and maintenance costs however, single-screw designs are more common in the feed industry. At present, the use of extrusion technology is limited to the production of companion animal and aquaculture feeds, where it is used primarily to change the sensory (e.g., shape) and physical (e.g., buoyancy) properties of the feed, as well as to eliminate any feed-borne pathogens (Plattner et al., 2006).

What canola meal and DDGS share in common is that both contain considerable levels of both protein and dietary fibre. The well-documented effects of extrusion on both of these constituents of feeds, therefore, suggest a potential for improvements in the feed value of co-products. There has been little work done to evaluate the potential of extrusion processing to enhance the nutritive value of canola meal for monogastrics. The lone relevant report in the literature (Keady and O'Doherty, 2000) found that while extruding solvent-extracted double-zero rapeseed (i.e., canola) meal slightly increased energy digestibility for grower finisher pigs, there were no effects on pig performance. We are not aware of analogous reports in the literature regarding extrusion of solvent-extracted canola meal fed to poultry.

Our group has, however, studied the application of extrusion technology to improve the nutritive value of DDGS for broilers. In one study, we compared nutrient digestibility of twin extruded wheat and corn DDGS for broilers (Oryschak et al., 2010a). We found that extrusion of both wheat and corn DDGS significantly increased apparent ileal digestibility of several key amino acids (**Table 2**).

Table 2. Effect of DDGS type and twin-screw extrusion on apparent total tract digestibility (ATTD) of gross energy and apparent ileal digestibility (AID) of selected amino acids for growing broilers (Oryschak et al., 2010a).

	DDGS Type		Extrusion			*P*-value	
	Corn	Wheat	-	+	SEM	Type	Extrusion
Gross energy	52.20[a]	48.44[b]	46.16[b]	54.49[a]	1.13	0.031	< 0.001
Arginine	77.24	80.46	73.58[b]	84.12[a]	1.14	0.052	< 0.001
Lysine	65.54	63.55	55.13[b]	73.95[a]	1.98	NS	< 0.001
Methionine	82.62	84.27	79.44[b]	87.46[a]	1.11	NS	< 0.001
Threonine	63.31[b]	68.28[a]	61.21[b]	70.38[a]	1.34	0.019	0.002
Tryptophan	69.92[b]	79.17[a]	72.47[b]	76.63[a]	1.33	< 0.001	0.013

Table 3. Effect of extrusion on apparent total tract digestibility of gross energy and apparent ileal digestibility of selected amino acids in triticale DDGS for growing broilers, based on 30% dietary inclusion, in %.

	Extrusion			*P*-values
	(-)	(+)	SEM	Extrusion
Gross energy	41.08[b]	44.92[ab]	2.10	0.012
Arginine	78.19	77.57	3.56	NS
Lysine	61.96	58.17	3.26	NS
Methionine	73.02[b]	81.18[a]	1.47	< 0.001
Threonine	60.34	59.47	3.09	NS
Tryptophan	69.98[b]	75.59[a]	1.81	0.002

In a second study, we studied the effect of single-screw extrusion of triticale DDGS on nutrient digestibility for growing broilers (Oryschak et al., 2010b). Though we observed improvements in digestibility energy and several amino acids, the improvements were not as consistent as what was observed in corn and wheat DDGS (**Table 3**).

There are several possible scenarios consistent with physical changes described in Table 1 that could account for how extrusion improved nutrient digestibility in DDGS. We hypothesized that extrusion increased nutrient digestibility in DDGS through having a differential effect on the solubles component of DDGS. Digestibility of amino acids in distillers solubles and DDGS is lower than in distillers dried grains for both poultry (Martinez-Amezcua et al., 2007) and pigs (Pahm et al., 2008). It might be expected therefore that the positive response (i.e., increased nutrient digestibility) would therefore be affected by the ratio of solubles to distillers grains in DDGS. This could account for the differences in response to extrusion we observed in triticale DDGS compared to corn and wheat DDGS. The other obvious implication is that extrusion may not yield consistent improvements in all situations.

The feasibility of extrusion for improving the nutritive value of co-products is limited by cost considerations. The additional cost associated with including an extrusion step in the production of either canola meal or DDGS is likely not justified by the marginal improvement in feed value. One potential, cost-effective application for extrusion might be as an alternative to the conventional drying steps in the DDGS production stream. Extrusion is capable of removing considerable amounts of moisture from a material, while at the same time enhancing nutrient digestibility.

It is also important to recognize that while extrusion may increase nutrient digestibility in co-products, it does not address the issue of nutrient dilution. In other words, the marginal improvement in digestible nutrient content achievable through extrusion is still limited by the total nutrient concentration in the co-product.

Enzyme supplementation

Use of exogenous enzymes to improve the quality of feedstuffs for monogastrics has been researched extensively for many decades. The basic principle of enzyme supplementation is to expand the array of enzyme activity in the gastrointestinal tract to allow degradation of a wider range of substrates. It has generally been thought that young animals with limited digestive capacity in particular could benefit from exogenous enzyme supplementation.

While the argument for enzyme supplementation of monogastric feeds has a strong basis in theory, empirical data reported in the literature paint a less clear picture. In some cases, enzyme supplementation of monogastric feeds has yielded measurable beneficial results, such as in the use of phytase to improve phytate phosphorus availability. In other cases, benefits of enzyme supplementation have not been observed or the marginal improvements have been insufficient to warrant supplementation from an economic standpoint. For an expanded discussion of enzyme supplementation in monogastric diets, the reader is encouraged to consult recent reviews by Adeola and Cowieson (2011) and Slominski (2011).

Enzyme supplementation as a means to improve the nutritive value of co-products for monogastric species has been an active area of research for the past decade. The outcomes of several of these studies are summarized in **Table 4**.

Table 4. Summary of experiments investigating the utility of exogenous enzymes to improve feeding value of co-products for monogastric species.

Reference	Test system	Description of study	Outcome
Jones et al. (2010)	Weaned pigs	Compared 3 enzyme products in nursery pig diets with 30% corn DDGS inclusion and enzyme supplementation of nursery diets with 30% dietary inclusion of corn or sorghum DDGS.	No positive effect on performance.
Zijlstra et al. (2004)	Weaned pigs	Studied effect of increasing CHOase supplementation levels in a wheat-canola meal diet fed to weaned pigs.	Enzyme supplementation increased ADFI and ADG, but not G:F.
Feoli et al. (2008)	Weaned pigs, finisher pigs	Studied effect of enzyme supplementation on nutrient digestibility and performance in nursery and finisher pig diets containing 30 and 40% corn and sorghum DDGS inclusions, respectively.	Small increase in digestibility of DM in the nursery phase and of DM, N and GE in the finisher phase. No effect on performance in either phase or carcass traits.
Emiola et al. (2009)	Grower pigs	Compared nutrient digestibility and performance of grower pigs fed 15 and 30% dietary inclusions of wheat DDGS with and without CHOase supplementation.	Enzyme supplementation improved nutrient digestibility and performance at 30% inclusion only.
Thacker (2001)	Grower-finisher pigs	Studied enzyme supplementation of barley-based diets containing canola meal fed to grower-finisher pigs.	No benefit of enzyme supplementation.
Jacela et al. (2010)	Grower-finisher pigs	Summarized four experiments with corn DDGS inclusions ranging between 15 and 60% dietary inclusion of corn DDGS fed to grower-finisher pigs with different enzyme products.	No beneficial effects of enzyme supplementation on ADG or G:F in any of the experiments.
Oryschak et al. (2010)	Broilers	Studied nutrient digestibility in broiler diets containing 15% or 30% inclusions of triticale DDGS with or without enzyme supplementation.	Small improvement in DM and CP digestibility, but no effect on digestibility of any AA.
Józefiak et al. (2010)	Broilers	Studied effect of phytase and carbohydrase supplementation of P-deficient diets containing 6 or 12% full fat canola seed on broiler performance.	Increased G:F in the overall 42-d experiment; attributed to increased digestibility of fat from canola seed.
Mushtaq et al. (2007)	Broilers	Compared performance and carcass traits of broilers fed corn-soybean meal diets containing 20 or 30% canola meal with or without enzymes	No effect of enzyme supplementation on performance or carcass traits
Kong and Adeola (2011)	Broilers	Studied the effect of phytase supplementation on protein utilization and amino acid digestibility of canola meal in broilers.	Small improvement in protein efficiency ratio, but no effect of phytase supplementation on AA digestibility or broiler performance.
Kocher et al. (2001)	Broilers	Studied effect of 2 enzyme products in sorghum-based diets with either soybean meal or canola meal as the sole protein ingredient.	Improvement of carcass traits relative to un-supplemented diets. Supplemented diets yielded similar response to soybean meal control.
Świątkiewicz and Koreleski (2006)	Laying hens	Studied egg production in laying hens fed diets containing increasing levels of corn DDGS up to 20%. NSP-degrading enzyme supplementation studied in 20% inclusion diet only.	No effect of enzyme supplementation in on any parameter measured throughout the study.
Jia et al. (2008)	Laying hens	Studied effect of NSP degrading enzyme on performance of laying hens fed diets containing 15% dietary inclusion of whole canola seed.	No effect on layer performance.
Buchanan et al. (1997)	Prawns	Studied effect of enzyme supplementation in prawn diets with moderate (20%) and high (64%) dietary inclusions of canola meal.	Large improvements in F:G and protein efficiency ratio at both inclusion levels.
Meng et al. (2005)	*In vitro*	Studied effects of different enzyme cocktails on *in vitro* degradation of cell wall polysaccharides in several ingredients including canola meal.	Increased *in vitro* degradation of various NSP fractions and total NSP. Did not study *in vivo* effects of enzyme on canola meal specifically.

The literature indicates that enzyme supplementation of monogastric diets containing co-products is not warranted based solely on improvements in nutrient digestibility of the co-products themselves. It should, however, be pointed out that enzyme technology is evolving, along with our understanding of these ingredients.

The results of Meng et al. (2005) suggest that perhaps direct enzymatic processing of these co-products as an end step in their respective manufacturing processes might be a better application of enzyme technology, as opposed to supplementation of mixed feeds. Another application deserving more attention is enzyme supplementation in diets containing expeller-pressed canola meal (10-12% residual oil), in light of the results reported by Józefiak et al. (2010).

Fractionation

The common goal of extrusion and enzyme supplementation is to improve digestibility of nutrients in a feedstuff. As mentioned previously, however, this approach does nothing to address the issue of the nutrient dilution effect of fibre in co-products, which is arguably the bigger concern. The basic goal behind fractionating co-products for monogastrics is to produce fractions with reduced fibre content and, therefore, higher densities of digestible amino acids and dietary energy.

Our research group has studied different fractionation techniques to improve the nutrient density in both wheat DDGS and canola meal. Our focus has been to develop processes that meet three key criteria, specifically that any technology be:

1) ***Cost-effective***: capital and operating costs associated with any fractionation process should permit a marginal economic benefit
2) ***Continuous***: a continuous fractionation process would likely be most efficient and easiest to incorporate into existing production systems.
3) ***Scalable***: any technology studied should be fully scalable to meet the needs of production facilities of varying size

Air classification

Air classification (or elutrition) uses air currents to separate a material into components differing in bulk density. Winnowing of grains in a light breeze to remove the light fibrous is an example of air classification in its simplest form. Modern air classification equipment operates under the same principle, but permits much tighter control over the production parameters. Many commercially available classification units use cyclonic air currents and centrifugal forces generated by turbines to increase the efficiency and precision of the separation process.

Our group has successfully separated pre-ground canola meal (98% < 100 μm) into fractions differing in fibre content using commercial air classification equipment. The result was heavy and light canola meal fractions differing in fibre, nutrient and glucosinolate content compared to the parent canola meals (**Table 5**).

Fractions produced in a first attempt using this process on a batch of solvent extracted *B. napus* meal were fed to growing broilers in a digestibility study (Oryschak et al., 2011b). Apparent ileal digestibility of several essential amino acids was higher in both fractions compared to a sample of unprocessed *B. napus* meal that was tested concurrently (**Table 6**).

Table 5. Analyzed nutrient content (%) and glucosinolate content of solvent-extracted B. napus and B. juncea meals and their air-classified fractions (from Zhou et al., 2013).

	B. napus			*B. juncea*		
	Parent meal	Light fraction	Heavy fraction	Parent meal	Light fraction	Heavy fraction
Crude protein	39.21	41.92	37.33	38.39	40.99	37.20
Crude fibre	9.72	0.26	8.73	6.81	0.37	8.35
Acid detergent fibre	20.12	13.13	25.58	12.88	8.58	16.52
Neutral detergent fibre	27.22	20.60	31.52	20.36	13.64	23.48
Lysine	1.95	2.36	2.05	1.93	2.11	1.81
Methionine	0.70	0.84	0.74	0.71	0.77	0.65
Threonine	1.43	1.72	1.54	1.54	1.68	1.46
Tryptophan	0.51	0.56	0.48	0.42	0.51	0.38
Arginine	0.92	1.12	0.98	0.98	1.08	0.91
Total glucosinolate, µmol/g	6.39	4.71	3.92	11.69	9.83	8.97

Table 6. Apparent ileal digestibility (%) of amino acids in *Brassica napus* canola meal compared to light and heavy air classified fractions fed to broilers (from Oryschak et al., 2011b)

	B. napus product				
	Unprocessed Meal	AC 'Light' fraction	AC 'Heavy' fraction	SEM	*P* - value
Lysine	77.46^{b}	85.89^{a}	87.35^{a}	1.36	0.001
Methionine	88.66^{b}	92.53^{a}	95.48^{a}	1.61	0.008
Methionine + Cysteine	76.80^{b}	85.33^{a}	87.53^{a}	2.12	0.012
Threonine	72.67	74.41	79.11	2.58	NS
Tryptophan	84.67	81.40	82.43	1.49	NS
Arginine	88.63^{b}	94.48^{a}	96.37^{a}	0.66	0.001
Total amino acids	78.19^{b}	86.22^{a}	89.66^{a}	1.45	0.001

A second set of fractions produced from samples of solvent-extracted *B. napus* and *B. juncea* meals were studied more extensively. Preliminary data from cannulated grower pigs shows that nutrient digestibility in the light air classified fraction was greater or equal to that of the parent stock meal (**Table 7**).

When these fractions were fed to nursery pigs or growing broilers (20% dietary inclusion), feed efficiency was highest for pigs and birds fed the light fractions (**Tables 8 & 9**). This confirmed that energy and digestible nutrient density was sufficiently greater in the light fractions compared to either the parent stock meals or heavy fractions to result in detectable improvements in growth performance.

Table 7. Main effect[1] of fraction type on apparent total tract and ileal digestibility (%) of dietary energy and nutrients in growing pigs (preliminary data from Zhou, unpublished).

	Canola fraction type				
	Parent stock	AC 'Light' fraction	AC 'Heavy' fraction	SEM	*P* - value
Apparent total tract digestibility, %					
Dry matter	74.2^{a}	76.7^{a}	70.2^{b}	0.8	< 0.001
Gross energy	74.1^{b}	78.0^{a}	71.3^{c}	0.9	< 0.001
Apparent ileal digestibility, %					
Gross energy	41.7^{b}	57.2^{a}	37.8^{b}	2.5	< 0.001
Crude protein	67.0^{a}	70.5^{a}	61.1^{b}	2.0	0.001
Lysine	72.9^{a}	75.5^{a}	68.0^{b}	2.1	0.003
Methionine	79.7^{ab}	81.8^{a}	76.7^{b}	1.9	0.012
Threonine	65.1^{ab}	70.5^{a}	60.1^{b}	2.2	0.001
Tryptophan	71.3^{b}	77.7^{a}	70.8^{b}	1.9	0.003

[1] Means are a combination of those for *B. napus* and *B. juncea*. There was no significant interaction between canola species and fraction type for any of the variables above.

Table 8. Main effect[1] of canola fraction type on overall (d 0 – 37) average daily feed intake, average daily gain and gain-to-feed ratio of weaned pigs fed diets containing 20% dietary inclusions of *Brassica napus* or *Brassica juncea* meals or their air classified light or heavy fractions (Zhou et al., 2013).

	Canola fraction type				
	Parent stock	AC 'Light' fraction	AC 'Heavy' fraction	SEM	*P* - value
Average daily feed intake, g/d	736.3	740.8	740.7	6.8	NS
Average daily gain, g/d	501.3	519.2	505.4	5.7	0.070
Gain:Feed, g/g	0.721^{b}	0.739^{a}	0.720^{b}	0.006	0.034

[1] Means are a combination of those for *B. napus* and *B. juncea*. There was no significant interaction between canola species and fraction type for any of the variables above.

Table 9. Main effect[1] of canola fraction type on overall (d 8 – 35) broiler growth performance, selected carcass traits and energetic efficiency of broilers fed diets containing 20% dietary inclusions of *Brassica napus* or *Brassica juncea* meals or their air classified light or heavy fractions (from Oryschak and Beltranena, 2013).

	Canola fraction type				
	Parent stock	AC 'Light' fraction	AC 'Heavy' fraction	SEM	*P* - value
Growth performance (d 8 – 35)					
Average daily feed intake, g/d	73.4^{b}	77.3^{a}	75.9^{a}	0.9	0.002
Average daily gain, g/d	97.1	96.4	98.2	1.5	0.698
Gain:Feed, g/g	0.757^{b}	0.807^{a}	0.774^{ab}	0.013	0.029

	Canola fraction type				
	Parent stock	AC 'Light' fraction	AC 'Heavy' fraction	SEM	*P* - value
Carcass traits (d 36)					
Ante-mortem weight, kg	2047.2[b]	2148.1[a]	2114.7[a]	22.2	0.003
Carcass weight, kg	1446.5	1441.2	1455.1	4.6	0.095
Dressing percentage, %	68.72	68.51	69.16	0.20	0.111
Starter phase (d 8 – 14)					
Calculated ingredient AME, kcal/kg	2588[b]	2805[a]	2498[c]	24	< 0.001
AME intake:liveweight gain, kcal/g	4.15	4.33	4.07	0.08	0.060
Grower phase (d 15 – 35)					
Calculated ingredient AME, kcal/kg	2202[b]	2495[a]	2100[b]	39	< 0.001
AME intake: liveweight gain, kcal/g	5.22	5.05	5.01	0.10	0.305

[1] Means are a combination of those for *B. napus* and *B. juncea*. There was no significant interaction between canola species and fraction type for any of the variables above.

Two-step dry fractionation

We have also studied a two-step fractionation process that, like the Elusieve process, involves first separating the parent material according to particle size by a Sweco model ZS30 vibratory sieving apparatus (**Figure 3**). This is then followed by a gravimetric separation the coarse fraction (i.e., large particle size) using a Westrup model LA-K gravity table. Using this process we have been able to generate wheat DDGS fractions differing in fibre and nutrient content (**Table 10**).

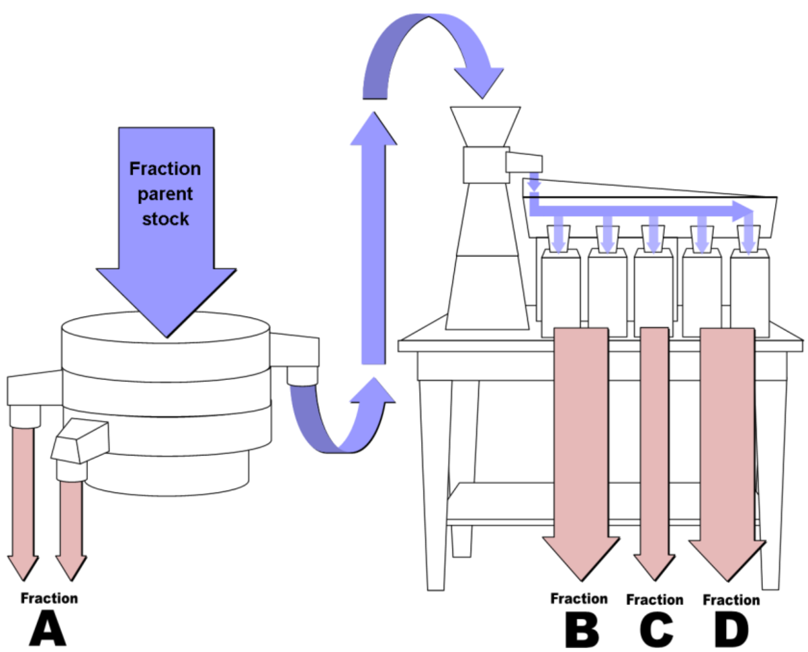

Figure 3. Two-step fractionation procedure used to generate 4 distinct fractions from wheat DDGS.

Table 10. Nutrient content of the 4 fractions generated from a wheat DDGS parent stock (from Oryschak et al., 2011a and Yanez, unpublished)

Nutrient	Wheat DDGS	DDGS Fraction A	DDGS Fraction B	DDGS Fraction C	DDGS Fraction D
Crude protein	39.4	52.7	43.3	38.0	31.9
Crude fat	4.06	2.9	3.6	3.3	3.0
Crude fibre	5.46	5.2	8.0	10.6	13.2
Acid detergent fibre	15.18	11.0	12.4	14.1	16.7
Neutral detergent fibre	35.17	27.6	31.9	43.4	44.2
Lysine	0.85	1.04	0.92	0.82	0.63
Methionine	0.55	0.74	0.58	0.49	0.36
Threonine	1.09	1.39	1.16	0.98	0.76
Tryptophan	0.42	0.39	0.33	0.31	0.24
Arginine	1.54	1.99	1.71	1.52	1.16

In addition to enhanced nutrient levels, we also sought to determine whether the differences in fibre among the fractions resulted in differences in nutrient digestibility. Nutrient digestibility of the fractions was compared to the parent stock wheat DDGS in broilers (Oryschak et al., 2011a). There were no significant differences in digestibility of energy or amino acid among the wheat DDGS or its three fractions (**Table 11**).

Table 11. Apparent total tract digestibility of gross energy and apparent ileal digestibility of selected amino acids in wheat DDGS and 3 wheat DDGS fractions fed to growing broilers (from Oryschak et al., 2011a).

	Wheat DDGS	DDGS Fraction				
		A	C	D	SEM	*P* - value
Gross energy	62.7	75.1	56.8	69.0	5.2	0.117
Lysine	73.5	67.3	69.8	77.3	5.4	0.548
Methionine	86.2	84.6	82.8	91.0	4.7	0.621
Methionine + Cysteine	83.7	79.9	78.4	86.4	5.1	0.662
Threonine	76.3	74.2	71.8	82.6	5.3	0.510
Tryptophan	85.0	76.7	81.2	84.8	3.6	0.327
Arginine	85.7	82.5	81.9	88.7	3.0	0.326
Total amino acids	85.2	81.2	80.7	86.6	4.2	0.662

The same comparison was made in cannulated grower pigs, with an additional comparison to soybean meal (Yàňez et al., submitted). Standardized ileal digestibility coefficients for the parent stock DDGS were generally not different from either soybean meal or fractions A and C. Coefficients for Arg, Lys and Trp were all highest for the D fraction compared to the other test ingredients (**Table 12**).

A common trend seen in both broiler and grower pig models was numerically lower digestibility in the A compared to the D fraction, despite higher concentrations of all fibrous fractions in the latter. Our interpretation of these findings is that the A fraction is where most of the solubles are concentrated. An additional implication of these data are that the major influence of fibre content in DDGS is nutrient dilution and that fibre content does not appear to be a major hindrance to amino acid digestibility.

Table 12. Standardized ileal digestibility of crude protein and selected amino acids in wheat DDGS, soybean meal and 3 wheat DDGS fractions fed to growing pigs (from Yàňez, submitted).

	Wheat DDGS	Soybean meal	DDGS fraction			SEM	*P* - value
			A	C	D		
Crude protein	77.3	75.5	79.6	75.7	86.4	2.8	0.060
Arginine	87.9^{b}	86.4^{b}	87.6^{b}	84.4^{b}	96.6^{a}	2.6	0.030
Lysine	71.2^{bc}	79.2^{b}	68.8^{bc}	67.6^{c}	90.1^{a}	3.7	0.001
Methionine	79.8	82.2	81.0	79.0	83.8	1.5	0.217
Threonine	78.4^{ab}	72.9^{b}	77.2^{b}	74.7^{b}	86.6^{a}	3.2	0.046
Tryptophan	84.0^{b}	81.8^{b}	83.9^{b}	80.8^{b}	94.9^{a}	2.4	0.002

In a 21-day growth and digestibility trial, Thacker et al. (2013) studied the graded replacement of the parent stock wheat DDGS for the ‘A’ fraction in wheat-soybean meal diets containing 20% wheat DDGS. They reported linear increases in dry matter and energy digestibility, as well as weight gain at 21 d of age as the fraction replaced the parent stock DDGS. These results appear to confirm that lower fibre DDGS fraction A has higher AME content compared with unmodified wheat DDGS.

Our group will be studying the application of this processing system to produce low-fibre, high protein canola meal fractions. Preliminary results suggest that it may be possible to generate acceptable yields of high crude protein, low-fibre fractions of canola meal by vibro-sieving alone (**Table 13**).

Table 13. Yield, protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) of different particle size fractions of solvent-extracted *Brassica juncea* meal generated by vibro-sieving using 2 different screen arrangements (from Beltranena and Zijlstra, 2011).

	Yield, %	Protein, %	ADF, %	NDF, %
Screen arrangement 1				
> 850 µm	33.4	41.5	15.0	22.8
< 850 µm	20.1	40.6	14.9	23.6
< 600 µm	19.0	42.9	12.0	18.6
< 425 µm	23.9	47.0	7.6	11.8

Summary

Canola meal and DDGS will continue to be important feedstuffs for the North American livestock sector. The key to increased utilization of co-products for monogastric species is reducing the anti-nutritive and diluent effects of fibre therein. The goal of extrusion and enzyme supplementation is to enhance nutrient digestibility, while fractionation has the potential both to increase nutrient density and digestibility.

Reports in the literature regarding enzyme supplementation suggest mixed results, however enzyme technology and our understanding of how best to use it are evolving. Extrusion has yielded positive results for the feed value of DDGS, but has generally received limited attention, most likely as a result of cost considerations. Fractionation has shown considerable promise for improving both nutrient density and digestibility of co-products (in particular canola meal). Further research however is required to optimize the fractionation process.

More research is required into cost effective post-production processing technologies to broaden the list of options to improve the feeding value of co-products for monogastric species. Optimizing the use of co-products is and will continue to be an important strategy for increasing feed competitiveness of pig and poultry producers in Western Canada.

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