

Estimating Displacement Ratios of Wheat DDGS in Animal Feed Rations in Great Britain

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Summary

Bioethanol production results in a co-product, distillers dried grains with solubles (DDGS) that is used in the animal feed industry. It has been generally assumed that DDGS will replace both soya and cereals in animal feeds and this assumption, together with the ratio ascribed, has been used to predict land use and other factors. This paper examines likely commodity replacement rates when wheat DDGS is used in Great Britain (GB).

A feed formulation model was constructed containing 51 finished feed specifications and 40 raw materials. Tonnages were assigned to each feed specification. The total market modelled was 13.2 Mt and included all feed fed to pigs and poultry plus retail compound feed fed to ruminants. Straights fed to ruminants on farm were excluded as accurate data was unavailable, so that the total ruminant feed market is under-predicted. Feed formulation used linear programming (Format International, Multimix and Parametrics) such that ingredients were used in feeds in which they were most cost-effective. Maximum volume constraints on some commodities were applied where domestic production is limited (for example maximum levels of oats, biscuit, peas and beans). Minimum volume constraints were also applied to home-produced raw materials on the basis that the price of these is likely to fall to ensure domestic usage (for example rapeseed meal, wheatfeed, sugar beet pulp). Prices used were September 2010.

The key findings of the study are:

- Wheat DDGS has a considerable higher value in ruminant feeds than it has in pig and poultry feeds. The main reason for this is that ruminants require a source of protein whilst pigs and poultry require amino acids. Wheat DDGS has a reasonable protein content but has a relatively poor amino acid concentration. Wheat DDGS has a higher value in ruminant feeds than extracted rapeseed meal whereas the converse is true in most pig and poultry feeds.
- Where the availability of wheat DDGS is limited, it is used almost exclusively in ruminant feeds and primarily replaces soya bean meal and mid-proteins (maize gluten feed, extracted sunflower meal) with little cereal replacement.
- As wheat DDGS availability increases greater quantities are used in pig and poultry feeds with soya bean meal and cereals being the main commodities replaced.
- With a high DDGS availability of 1.62 Mt (12.4% of total feed) approximately 0.95 Mt (59%) is used in ruminant feeds with the remainder equally utilised in pig and poultry feeds. Soya bean meal replacement rate was 0.29 (pig 0.25, poultry 0.37, ruminant 0.28) and cereal 0.28. Other commodities replaced by wheat DDGS included extracted sunflower meal (0.18), maize gluten feed (0.13) and palm kernel extractions (0.12).

- Doubling the price of soya increased DDGS usage marginally to 1.7 Mt. This then represents the maximum available Great British market for wheat DDGS using current typical feed specifications. Feed specifications evolve with prevailing commodity prices and should wheat DDGS prove inexpensive then feed specifications may be modified to increase usage.
- Further halving the crystalline amino acid price, and offering crystalline arginine and isoleucine (not currently commercially available), in addition to the five amino acids already offered, increased DDGS usage only marginally but dramatically reduced soya bean meal usage.
- Whilst there are differences in both feed commodities used in the EU and the percentage feed allocated to ruminants, pigs and poultry, it is not believed that these are of a sufficient magnitude to fundamentally affect the conclusion that DDGS will be preferentially utilised in ruminant feeds. However, the replacement rates will differ from country to country.

It is concluded that the replacement values for wheat DDGS in a market are complex and depend upon a number of factors including the species mix, the quantity of DDGS available, and the amount and price of other commodities available. Soya bean meal is consistently replaced by wheat DDGS but cereal replacement is highly dependent upon the species being fed, with poultry having a high cereal replacement whilst for ruminants cereal replacement is negligible as mid proteins are replaced. It is further concluded the value of wheat DDGS is considerably higher in ruminant feeds than monogastric feeds. This research then challenges the concept that wheat DDGS replacement is a simple function of cereal and soya bean meal replacement.

Units

In this report we refer to Mt (million metric tonnes) and kt (thousand metric tonnes)

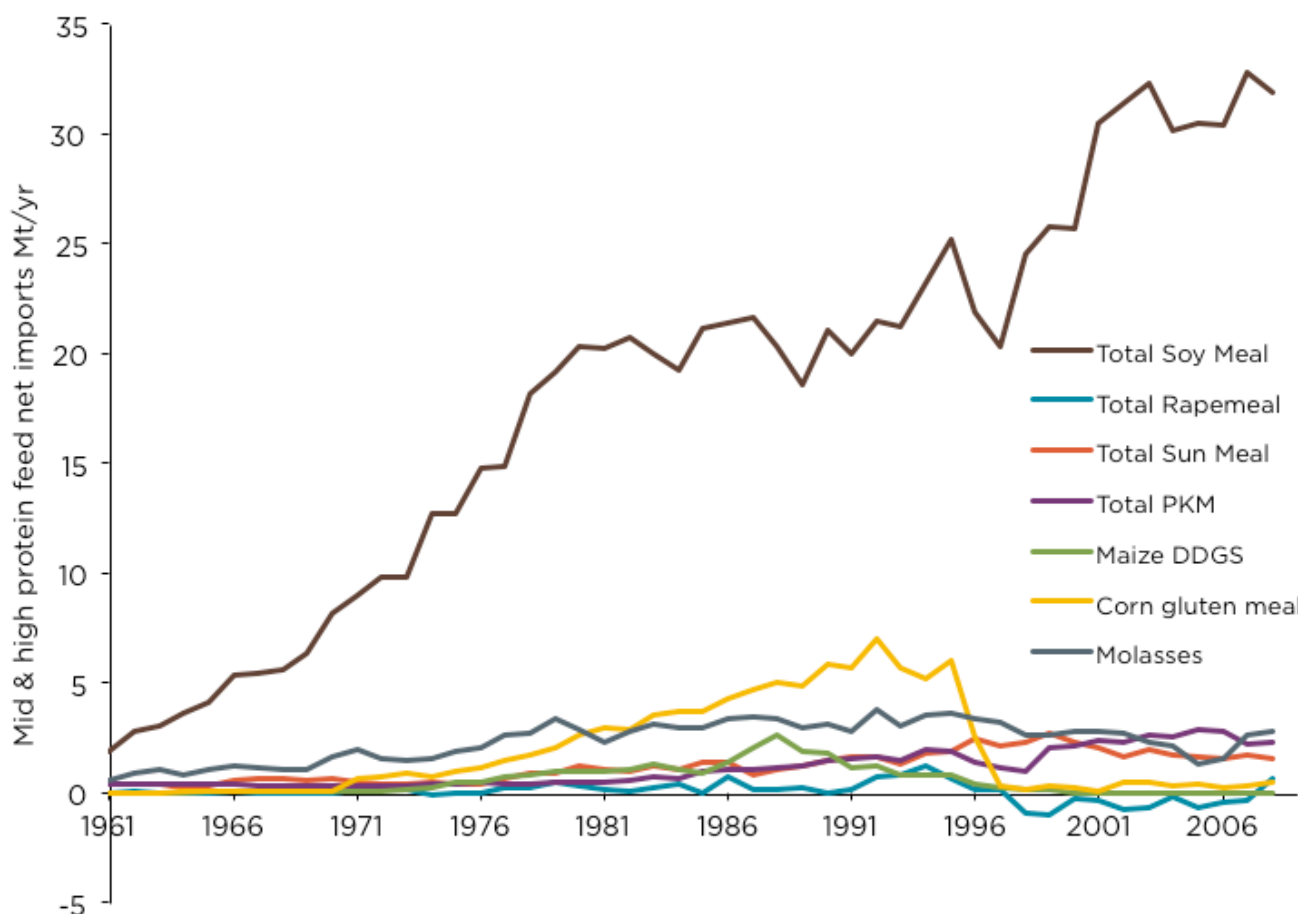


Figure 1. EU animal feed net imports 1961 - 2008 (FAO, 2011)

1. Introduction

Farm animals require nutrients in specified amounts specifically for the species concerned in order to produce meat, milk and eggs. Nutrient requirements vary widely. Ruminant animals can readily digest fibrous feedstuffs, whereas fibre digestion in monogastrics (pigs and poultry) is very limited. Monogastrics require certain essential amino acids in their feed, in the correct balance, if they are to be productive. Ruminants are much less reliant on the feed as a supply of amino acids as some can be manufactured by the rumen microflora. The younger the animal, the more nutrient dense the feed should be as nutrient requirements are relatively high compared to appetite.

Nutritionists have a number of feed specifications which define the nutrients required for a particular circumstance, together with raw material specifications and prices (Table 1). Linear-programming is used to derive the formulation at "best cost". Compound feed mills generally produce new feed formulations monthly as ingredients prices, availability and quality change.

Table 1. Example UK feed specification (Pelleted pig feed for feeding from 30-65kg, simplified)

Raw material	Min %	Max%	Nutrient	Min	Max
Barley	15	30	Oil (%)	3.75	5
Wheat	0	50	Protein (%)		
Wheatfeed	0	15	Neutral detergent fibre (NDF) (%)	0	15
Biscuit	0	10	Net energy (MJ/kg)	9.75	10
DDGS	0	12.5	SID lysine %*	1.05	
Extracted Rapeseed meal	0	10	SID Met/SID lysine*	0.32	
Extracted soya bean meal	0	30	SID M+C/SID lysine*	0.6	
Fat	0.5	3.0	SID Threonine/SID lysine*	0.65	
Lysine HCL	0	0.6	SID Tryptophan/SID lysine*	0.19	
Methionine	0	0.2	SID valine/SID lysine*	0.68	
Threonine	0	0.3	Calcium (%)	0.75	0.8
Limestone	0	1.2	Digestible phosphorus (%)	0.28	
Monocalcium phosphate	0	1.0	Sodium (%)	0.16	
Salt	0	1.0	SID - Standardised ileal digestibility		
Trace elements/vitamins	0.2	0.2	Met - Methionine; M + C - Methionine + Cysteine		

*Standardised ileal digestible amino acids and amino acid ratio's

2. Bioethanol production in the UK

The first wheat bioethanol plant in the UK was established in 2010 by Ensus (<http://www.ensusgroup.com>) on Teesside in North East England. Ensus refines over 1 Mt of locally grown wheat to produce over 400 million litres of bioethanol, 350 thousand tonnes of high protein animal feed, and 300 thousand tonnes of carbon dioxide for use in soft drinks and food production each year. In May 2011, Ensus had announced the temporary closure of the plant due to negative margins.

Vivergo Fuels (<http://www.vivergofeeds.co.uk>) is of a similar size to the Ensus plant and is expected to be fully operational in 2012 producing around 420 million litres of bioethanol from approximately one million tonnes of British feed wheat per annum. In addition to producing bioethanol, the plant will produce around 0.5 Mt annum

The UK, in common with most of Europe, has for many years used both domestically produced and imported feedstuffs. This has led to sophisticated methods for evaluating a wide range of feed commodities so their value can be precisely determined and they can be used without any deterioration in animal performance. This is in contrast to the U.S. where historically feeds have been heavily reliant upon two commodities, corn and soya. In the U.S, a number of papers have been published where it has been suggested that corn DDGS displaces a certain percentage of soya and of corn (possibly with a comment on fat and phosphorus addition). Such a simplistic model may not be valid for Europe with its larger range of feed commodities.

This report examines in detail the impact of wheat DDGS on feed ingredient use in Great Britain. A feed formulation model has been built, containing 51 feed specifications (12 pig, 18 poultry, 21 ruminant), which can assess wheat DDGS replacement ratios, under various cost and supply scenarios, into a total feed market of 13.2 Mt.

of wheat DDGS (0.39 Mt dried pelleted, 0.13 Mt moist) together with 25 kt of liquid wheat distillers syrup.

Thus the UK will use 2 Mt of wheat for bioethanol (from an average exportable surplus of 2.4 Mt) retaining the equivalent of around 0.75 Mt of dried wheat DDGS. It should be noted that the majority of wheat DDGS available in the UK will be dried, that is, at a dry matter of around 10%, rather than as a moist feed. When dried the DDGS has excellent storage characteristics and can be easily transported, particularly if pelleted. This is contrast to other markets, such as the US, where considerable quantities of moist DDGS are fed to cattle in feedlots. The UK does not have feedlots in a scale comparable to the US and the cattle are largely found in the West of the country whilst the bioethanol production is in the East.

An alternative way to examine this is the UK is losing

about 1.3 Mt of wheat starch but is retaining the fat, protein, fibre and minerals in the DDGS. Additionally, some of the amino acids from the wheat are also lost and with some reductions in amino acid digestibility, caused by heat damage in the bioethanol manufacturing process.

3. Livestock production in the Great Britain

The human population of the UK is about 62 million and the land area just in excess of 93,000 square miles. The west has a higher rain fall and generally higher land and is more suitable for grass whilst the drier and flatter lands in the east are more suitable for cereals. The UK is productive both in terms of grass growth and cereal yields/hectare. Generally, the mono-gastric population is concentrated in the east, where the cereals are grown, and ruminants in the west where grass is plentiful.

Total annual feed production in Great Britain (GB) in 2010 is estimated at 2.5 Mt for pigs and 6 Mt for poultry. Retail sales to ruminants were 4.7 Mt. Unfortunately, there are no reliable estimates of feed straights fed to ruminant animals on-farm in home mixed diets.

4. Feedstuffs used for feeding livestock in Great Britain.

Monogastrics are fed complete feeds, either mixed in compound feed mills or on-farm. The composition and

amount of feed can be estimated with a reasonable degree of accuracy as much of the information is collected by government statute (Department Environment Food and Rural Affairs, Defra).

In contrast, the majority of ruminants are fed complementary feeds as a supplement to grazing, the feeding of preserved forages such as silage and hay, or other moist feeds. The complementary feeds are supplied as pelleted compound feeds (which contain minerals and vitamins) or as raw material blends. Both retail sales of compounds and blends are recorded by Defra (2011a and 2011b), as is poultry feed used by integrated companies. Feed mixed on farm for pigs can be estimated from pig slaughterings and typical performance data. Regrettably we have been unable to find reliable estimates of straights fed to ruminants on-farm.

Great Britain *retailed* 9.9 Mt of compound animal feed in 2010 and the average composition of this feed is shown in Table 2. This is retail feed and so excludes feed used by integrated poultry companies, and feed mixed on-farm for pigs and ruminants.

4.1. Cereals

Cereals comprise approximately 40% of GB retail feed (0.4 Mt) the vast majority of which is home-grown. The UK produces an average 14.8 Mt of wheat (2005/6-2009/10 average) of which 6.6 Mt are used for animal feed. Exports amount to 2.4 Mt over the same period. As mentioned

Table 2. Raw materials used in compound retail feed production in the UK (2010)*

	GB retail feed sales 2010	
	kt	%
Wheat	2789.9	28.2
Barley	931.7	9.4
Oats	111.4	1.1
Whole/flaked maize	106.1	1.1
Rice bran	15.6	0.2
Maize gluten feed	104.2	1.1
Wheatfeed	841.5	8.5
Confectionary/biscuit	184.9	1.9
Other cereal byproducts	162.5	1.6
Distillery byproducts	307.6	3.1
Whole oilseeds	57.6	0.6
Extracted rape meal	764.3	7.7
Extracted soya bean meal	1141	11.5
Extracted sunflower meal	245.9	2.5
Other oilseed cakes/meal	429.5	4.3
Field beans	102	1.0
Field peas	35.5	0.4
Dried sugar beet pulp	271.5	2.7
Molasses	256	2.6
Citrus pulp	65.8	0.7
Fish/poultry meal	109.7	1.1
Minerals	434.7	4.4
Fats	181.2	1.8
Protein concentrates	14.2	0.1
Other	239.2	2.4
Total	9903.5	

* Excludes integrated poultry and pig feed mixed on-farm (Defra, compound feedingstuffs survey)

previously, when in full production the Ensus and Vivergo bioethanol plants will use around 2 Mt of wheat. Barley production was 5.7 Mt in the same period, 3.1 Mt being used in animal feed with barley exports at 0.7 Mt. Oat production is relatively small at 0.7 Mt and grain maize negligible. There are small imports of grain maize much of which is used for flaking and fed to young animals.

4.2. Cereal by-products

Cereal by-products (rice bran, maize gluten feed, wheatfeed, confectionary, distillery by-products, and other cereal by-products) comprise a further 16.4% of GB retail feed.

Wheatfeed (also known as middlings, sharps) is the most commonly used cereal by-product. Most of this is home-produced. The UK mills 6.1 Mt of wheat/annum which, with an estimated 80% flour yield, suggests a production of wheatfeed (and bran) of around 1.22 Mt. By-products from human foods (biscuit, bread, dough, sweets, etc.) are also widely used in animal feed and are referred to as "confectionary" or "biscuit" meals although are traded under proprietary brands. Companies dry and blend these materials and a number of dry products are produced. It is estimated that UK production of this type of material is around 0.6 Mt.

Distillery by-products yielded just over 3% of UK feed (308kt) in 2010. Historically, most distillers would have been from whisky production (Scotland) or corn distillers with solubles from the USA. The importation of US corn distillers has been disrupted by GM legislation. This was resolved early in 2010 and currently maize gluten looks attractive in UK feeds. However, this may be disrupted again in 2012 with further GM maize varieties being approved and used in the US but which are not yet approved by the EU. On average from 2005-2009, distillers use in GB retail feeds averaged 217kt/annum, with 2010 seeing an increased use of 91kt. Some of this will be wheat DDGS from the new bioethanol plant.

Maize gluten feed and rice bran are the remaining major cereal by-products, both of which are imported. Maize gluten feed is produced as a by-product in the production of maize flour by the wet milling of maize grain. Maize gluten feed imports have also been disrupted by GM registration issues noted above.

"Other cereal by-products" used in GB retail feeds total 162.5kt. Products included are not specified but are likely to include maize germ and maize meals (although these may perhaps also get coded to whole/flaked maize), oatfeed and oat by-product meal and possibly some biscuit meal not recorded under confectionary.

4.3. Proteins

Soya bean meal usage at 1.14 Mt (11.5%), remains the major protein source in GB retail feeds and is imported with the majority from South America (Figure 1). Total UK soya bean meal used for animal feed is estimated at 2.4-2.6 Mt. Of this, approximately 1 Mt is Argentinean and 0.8 Mt is Brazilian whilst a further 0.4-0.5 Mt is believed produced in the UK (although there is no official crushing data). Some

75% of the imported beans for UK crushing are Argentinean, whilst some are supplied via the Netherlands and are also likely to be of South American origin. There are various grades of extracted soya bean meal; the soya used in the UK typically has a protein of 46.5-50% depending upon source, processing and season. The broiler industry and feed for organic production uses non-GM soya meal which is of South American origin.

Rapeseed, predominantly of UK origin, is increasing in importance and use in GB feeds has increased from 0.53 Mt in 2000 to 0.76 Mt (7.7%) in 2010. Both the domestic production of rapeseed in the UK and the usage of rapeseed meal are set to increase. Genetic improvements in rapeseed have made the meal more suitable for livestock feeding, particularly to mono-gastric animals and its price has been attractive. Historically, rapeseed meal was not used in laying birds as it can lead to egg taint in brown birds. Genetic selection of the layers has now largely removed the "tainters" so that increased rapeseed meal is likely in poultry. UK rapeseed exports in 2009/2010 were almost 100kt.

Sunflower contributes to more than 20% of EU oilseeds production and is the largest oilseed crop after rapeseed. In 2008, Russia was the largest sunflower producer in the world (7.35 Mt) followed by the EU (7.13 Mt) Ukraine (7 Mt) and Argentina (2.44 Mt). Sunflower meal was included at 2.5% in GB retail feeds sales in 2010, primarily in ruminant and layer feeds. Sunflower meal is purchased according to protein content with 28/29% and 32/33% protein being the most popular although "hipro suns" with a protein of 38% is also sometimes available. Sunflower is very much a "feast and famine" raw material in the UK in that sometimes it is very cost-effective and floods into feed formulations, the next it is hopelessly uneconomic. This does not appear to be seasonal. Premiums for 32/33% protein material range from £5-20/t over the 28/29% with 38% protein trading at a premium of £30-40/t when available. The major supplier of the 28/29% sunflower is the EU, whilst the 32/33% is mainly Argentinean. Some high protein sunflower has been imported from the Ukraine. Supply of Argentinean sunflower was poor in 2010.

"Whole oilseeds", totalling 0.6% of GB retail feed, will include whole rape which is used predominantly in the broiler sector. It could contain extruded whole soya beans although these are more likely to be recorded under soya meal.

"Other oilseeds and cakes" are significant at 0.43 Mt, 4.3% of GB retail sales. This category is defined as "coconut, palm kernel, shea and illipe nuts or any other oilseed or nuts not included in the cakes and meals categories". It is thought that this will be very largely palm kernel (PK) meal. UK imports of PK meal ranged from 533kt to 835kt in the years 2003-2007 (Eurostat), with Malaysia and Indonesia supplying well in excess of 90% of this.

Domestically produced peas and beans total 1.4% of GB feed retail sales. The production and use of beans has increased slightly but that of peas decreased. Pulses grown for animal feed have not yielded the margins/hectare of rapeseed and where a pulse is required for rotational reasons, beans are easier to grow and harvest

than peas. Most of the peas used in animal feed are reject from human consumption.

4.4. Other raw materials

The UK is a large producer of sugar from sugar beet and the residue, sugar beet pulp, is widely used (2.7% of GB retail sales) in cattle feed where it is an excellent source of digestible fibre (imported citrus pulp and soya hulls may be used as an alternative to sugar beet). The process also produces beet molasses which combined with imported sugar cane molasses comprises 2.6% of GB retail sales. Molasses is very palatable to all livestock species and improves pellet quality and handling characteristics of some meals although it is largely used in ruminant feeds.

Animal by-products at almost 110kt, 1.1% of GB retail sales, led to some confusion in understanding the feed market. Meat and bone, blood meal, poultry offal and other animal

products are not allowed as feed ingredients in Great Britain following legislation introduced after the outbreak of Creutzfeldt-Jakob disease (CJD). Further, fish meal is not allowed to be fed to ruminants as it invalidates tests for mammalian protein, which were introduced as part of legislation to control CJD. This quantity of fishmeal could not be used in only poultry and pig feeds. However, in the retail production of feeding stuffs in GB there is a category, of 368kt, entitled “other compounds, blends and concentrates” Much of this is believed to be fish feed manufacture which is estimated at 300-350kt; hence most of the fishmeal is used in fish feed manufacture.

Finally, fats comprise 1.8% of GB retail feed sales. Pure oils (soya, sunflower, palm), acid oils (soya, rape, sunflower) and fat blends (combinations of acid oils and pure oils) are used. Acid oils are the residue produced when glycerol is removed from fat. Unsaturated (soft) fats are preferred for monogastrics and saturated (hard) fats by ruminants.

Table 3. Proximate analysis of the wheat DDGS used in the formulation exercises (GB origin)

Dry matter	%	92.5	Ash	%	4.20
Crude protein	%	33.0	Calcium	%	0.10
Oil (A)	%	4.6	Phosphorus	%	0.60
Oil (B)	%	7.5	Sodium	%	0.38
Crude Fibre	%	9.4	Chloride	%	0.21
Neutral Detergent Fibre (NDF)	%	30	Magnesium	%	0.23
Acid Detergent Fibre (ADF)	%	23.0			
Starch	%	3			
Sugar	%	3			

Table 4. Energy and amino acid analysis of the wheat DDGS used in the formulation exercises (GB origin)

		Pig	Poultry	Ruminant
Net energy pig grow (NEg)	MJ/kg	8.00		
Net energy sow (NEs)	MJ/kg	8.85		
Poultry metabolisable energy (AMEPn)	MJ/kg		9.94	
Ruminant metabolisable energy (ME-R)	MJ/kg			11.2
Digestible amino acids				
Lysine	%	0.55	0.47	
Methionine	%	0.36	0.36	
Methionine+Cystine	%	0.86	0.76	
Threonine	%	0.81	0.70	
Tryptophan	%	0.23	0.20	
Isoleucine	%	0.90	0.88	
Valine	%	1.23		
Histidine	%	0.67	1.83	
Arginine	%	1.06	0.07	
Digestible undegradable protein (DUP)	g/kg			98

5. Defining wheat DDGS

There is variation in the nutrient analysis of all feed commodities. Wheat DDGS is highly variable, probably more so than any other feed material. This variability arises from a large number of factors. Heat damage is probably the most significant factor as this leads to thermal destruction of some amino acids as well as a reduction in amino acid digestibility. The efficiency of the plant influences residual starch and sugar levels. Further, the amount of solubles added back to the distillers grains is also important. Newer bioethanol plants have been better designed to optimise the nutritional value of the DDGS and the scientific literature often refers to the feeding value of “old” and “new” DDGS.

The specification of GB DDGS used in this study is shown in Tables 3 and 4 and is of a relatively high quality as judged by amino acid recovery. Most of the numbers in this specification have been derived over 3 consecutive months from actual analysis. The exceptions are the energy values and some of the ruminant numbers which have been estimated from the scientific literature.

A comparison of wheat DDGS to other major commodities used in the UK is shown in Table 5.

Monogastrics are fed complete feed and the major nutrient costs are energy and essential amino acids. Poultry feeds are formulated to metabolisable energy (ME) in the UK whilst pig feeds are formulated to net energy (NE) which additionally takes into account the heat losses of the animal. In both species, fibre is a major determinant of energy, with high fibre levels reducing digestibility. Wheat DDGS has about 4% less energy than extracted soya meal but 20-40% more energy than extracted rape meal. It has about 17% less energy than barley and 25% less energy than wheat. The digestible amino acid content of wheat DDGS is typically 2-3 times that of cereals, and is superior to wheatfeed, but is inferior to peas and beans and much worse than extracted rape or soya meal.

In contrast, ruminants are fed complementary feeds with the major nutrient costs being crude protein, digestible undegradable protein (DUP) and energy. The rumen has microbes that are adept at digesting fibre so that the negative effects of fibre on energy digestibility are much

Table 5. Wheat DDGS in comparison to other major feed ingredients used in the UK

		Wheat	Barley	Wheat feed	Maize gluten feed	Wheat DDGS	Extract. Rape seed meal	Extract. Soya bean meal	Extract. Sunfl. meal
Oil	%	2.3	2.6	4.5	3.5	7.5	5.0	2.6	2.2
Protein	%	11.0	10.0	15.4	20	33.0	33.9	48.0	31
Crude Fibre	%	2.0	4.8	8.5	8	9.4	12.0	3.7	24
NDF	%	8.5	16	34	34	30.0	22.0	7.5	36
Net Energy pig	MJ/kg	10.61	9.66	7.62	6.89	8.00	6.51	8.44	5.1
Metabolisable energy - poultry	MJ/kg	13.00	11.80	8.50	8.2	9.94	7.00	10.30	6.5
Metabolisable energy - ruminant	MJ/kg	11.9	11.35	10.3	11.5	11.2	10.60	12.30	8.7
Digest. Lysine*	%	0.26	0.28	0.45	0.41	0.55	1.37	2.69	0.87
Digest M+C*	%	0.38	0.31	0.41	0.52	0.86	1.21	1.18	1.04
Digest Thr*	%	0.27	0.27	0.37	0.49	0.81	1.07	1.67	0.92
Digest Tryp*	%	0.11	0.10	0.17	0.09	0.23	0.34	0.58	0.33
Digest valine*	%	0.41	0.38	0.53	0.72	1.23	1.30	2.01	1.26
DUP**	g/kg	24	12	39	26.2	98	67	159	57.2

* Standardized ileal Digestible for pigs.

**digestible undegradable protein (ruminants).

less pronounced than in monogastric animals. Feeding is complex involving potential combinations grazing, roughage, compound feeds, blends and protein concentrates.

Wheat DDGS has a similar protein level (33%) to rapeseed meal (33.9%) and sunflower meal (31% used in this exercise although products available from 28 to 38% protein). This group tend to be referred to as “mid proteins”. Extracted soya meal typically averages 48% protein. For ruminants, wheat DDGS is a good source of DUP, second only to soya. The metabolisable energy value of wheat DDGS for ruminants is inferior to soya meal but is superior to rape

and sunflower meal.

6. Modelling GB feed ingredient use and the impact of wheat DDGS

The GB feed market (excluding straights fed to ruminants on-farm) was defined using 51 feed specifications, each of which had an appropriate tonnage allocation. This is detailed in the appendix (Appendix: Estimations of feed market size, feed specifications and tonnage allocation).

Raw materials offered were largely those recorded by Defra (Table 2). Raw material costs used were typical of September 2010, although inevitably prices and raw material vary around the UK. Tonnage constraints (i.e. indicating national availability) were applied to some raw materials, such as oats, beans and peas, and biscuits. These estimates are what we believe were typical in 2011. Some commodities have relatively constant tonnage availability, such as wheatfeed and biscuit, whereas others are more reactive to market prices, such as whether wheat or barley is grown, or pulses or rapeseed instead.

Linear programming (Format, Multimix and Parametrics) was employed to generate 51 formulations, at least cost, using the raw materials on offer. Each formulation had a tonnage estimate so that a raw material breakdown for the

13.2 Mt of feed defined in the model could be produced.

It should be noted that

- Feed formulation is very sensitive to raw material prices. For example a price of £152/t has been used for barley and £161/t for wheat. A change of £1/t in this price can markedly influence the ratio of wheat to barley used in the formulation. Cereal prices can change as much as £10/t in a day!
- As noted earlier continuity of supply/price can be difficult for some raw materials. Sunflower is a good example. Additionally in 2010 the mid protein market was disrupted due to a fire at one the rapeseed crushing plants which led to a temporary shortage in rapeseed, imports of meal, and elevated prices.

Table 6. A comparison of actual raw material use in GB retail feed sales in 2010 to modeled use.*

	GB retail feed sales 2010		Modelled GB retail feed sales (Sept 2010 costs)		Comments
	kt	%	kt	%	
Wheat	2789.9	28.2	2443.1	26.5	
Barley	931.7	9.4	1346.2	14.6	
Oats	111.4	1.1	100.0	1.1	Maximum
Whole/flaked maize	106.1	1.1		0.0	
Rice bran	15.6	0.2		0.0	
Maize gluten feed	104.2	1.1	100.0	1.1	Maximum
Wheatfeed	841.5	8.5	825.0	9.0	Maximum
Confectionary	184.9	1.9	76.5	0.8	
Other cereal byproducts	162.5	1.6	96.3	1.0	Bakery meal
Distillery byproducts	307.6	3.1	275.0	3.0	Maximum
Whole oilseeds	57.6	0.6	40.0	0.4	Rape seed
Extracted rape seed meal	764.3	7.7	780.0	8.5	Maximum
Extracted soya bean meal	1141	11.5	1204.0	13.1	
Extracted sunflower meal*	245.9	2.5	230.0	2.5	Maximum
Other oilseed cakes/meal	429.5	4.3	374.0	4.1	Palm kernel
Field beans	102	1.0	100.0	1.1	Maximum
Field peas	35.5	0.4	33.0	0.4	Maximum
Extruded pulse/rape			32.5	0.4	
Dried sugar beet pulp	271.5	2.7	373.0	4.0	
Molasses	256	2.6	223.0	2.4	
Citrus pulp	65.8	0.7	60.0	0.7	Maximum
Soya hulls			50.0	0.5	Maximum
Fish/poultry meal	109.7	1.1	18.5	0.2	
Minerals	434.7	4.4	280.0	3.0	
Fats	181.2	1.8	106.5	1.2	
Protein concentrates	14.2	0.1		0.0	
Other	239.2	2.4		0.5	
Total	9903.5	100	9212	100.0	

* Specified at 31% protein

- Specifications for pig and poultry feed that define the UK market can be given with some confidence, as they vary to a relatively small degree from mill to mill, farm to farm. This is certainly not the case with ruminant feeds and particularly with ruminant blends. Blends can be formulated to a specification but may simply be a fixed formulation (for example a third soya bean meal, a third rapeseed meal, a third sugar beet pulp). Many blends will be bespoke. Furthermore, farmers have their own perceptions on what constitutes a good or poor quality raw material, and that perception can differ geographically. Finally, the maximum percentage inclusion rates of raw materials in blends will be related to the feeding rate. Therefore any modelling of the blend sector will be somewhat simplistic.

6.1. The model “fit” to raw material use in GB retail feeds in 2010

As an approximate validation of the model, raw material usage was predicted for GB retail sales and compared to actual Defra recorded usage. The total tonnages are unequal as the Defra retail sales contain 0.7 Mt of horse feed and “other compounds, blends and concentrates” which are believed to be mainly fish feed. Some constraints on market raw material availability were employed. Furthermore, September costs are used rather than annual costs.

Initial runs indicated a good prediction of cereals but an under use of soya and overuse of rape and sunflower meal. As indicated previously, both the supply of sunflower and rapeseed meal was limited in 2010. The model was therefore re-run with restrictions on the supply of these commodities (Table 6).

Cereal usage in the model was 42.2%, compared to an actual usage of 39.8%, with cereal by-products modelled at 11.9% compared to 13.3%, so that total cereal plus cereal by-product use was estimated at 54.1% compared to the Defra figure of 53.1%.

Soya bean meal usage was 13.1% in the model compared to the actual 11.5% and rapeseed meal was also slightly

higher at 8.5% compared to actual 7.7%. As mentioned earlier, rapeseed supply in 2010 was disrupted by a fire as a crushing plant which may explain the differences in rapeseed meal usage. Reducing rapeseed meal used in the model by 0.1 kt increases sunflower meal, DDGS and wheatfeed usage and has a negligible influence on soya meal. Again, though sunflower meal supply is erratic and such volumes may not be available.

Sugar beet pulp usage was higher than actual; molasses and citrus use were in good agreement. Mineral use prediction was low but there are no protein concentrates in the model (tonnage is assigned to blends) which will account for some of this. Fat usage is also low. Fishmeal use is very low but this is understandable as fish feed (0.3 Mt) which contains large quantities of fish meal was not modelled.

The formulation model gives a reasonable prediction of commodity use within the GB feed market. It is suspected that the model may be slightly over-using protein but this cannot be confirmed because of undefined categories (such as “other oilseed cakes”; “other compounds, blends and concentrates”) in the Defra statistics and the fact that fish and horse feeds are not included in the formulation model.

6.2. Estimates from the feed formulation model

The full model, including pig home-mix and poultry integrated tonnage, is used in the following examples. It is assumed that 275 kt of distillers products are already available for feeding.

6.2.1. Baseline with 0.77 and 1.00 Mt of wheat DDGS offered (Table 7)

Offering 0.77 Mt of wheat DDGS resulted in all but 2 kt being used in the ruminant sector. Wheat DDGS mainly replaced soya meal (0.33 replacement), sunflower meal (0.30) and rape meal (0.22). Additional barley was used (0.24) and less wheat (0.33). When the total DDGS available was increased to 1 Mt some 30 kt were used in pig and 43 kt in poultry. Wheat DDGS again replaced largely soya meal (0.24), sunflower meal (0.21) and rape

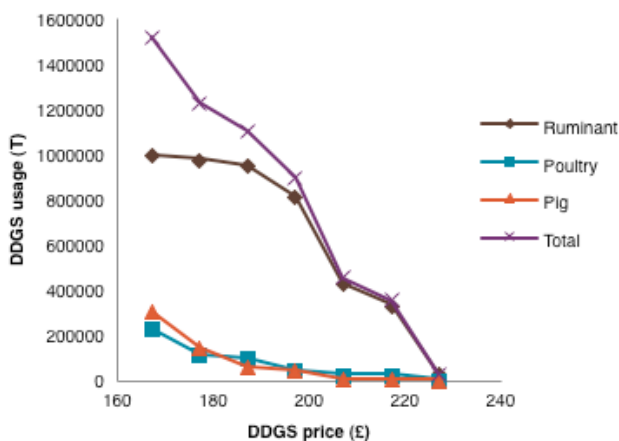


Figure 2. The volume of wheat DDGS used in GB feed at various prices

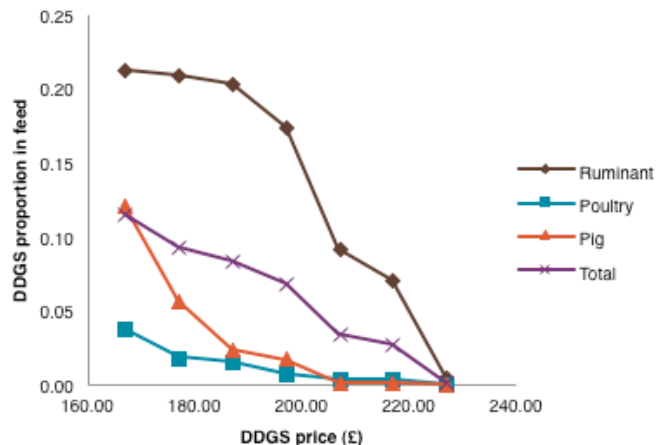


Figure 3. The proportion of wheat DDGS used in GB feed at various prices

Table 7. Multimix of total GB feed market (13.2 Mt excludes on-farm straights fed to ruminants)**Run 1**

	Price	Market limit	Raw material use					
	£/t	t	tonnes	(%)	t	Replacement	t	Replacement
Wheat DDGS	197		275,000		775,000		1,000,000	
Barley	152		1,085,038	8.2	1,203,759	-0.24	1,287,721	-0.28
Wheat	161		5,140,867	39.0	4,977,169	0.33	4,923,342	0.30
Oats	125	110,000	100,000	0.8	100,000	0.00	100,000	0.00
Wheatfeed	141		825,420	6.3	874,575	-0.10	877,845	-0.07
Bakery meal	170	175,000	175,000	1.3	175,000	0.00	175,000	0.00
Confectionary meal	185	175,000	175,000	1.3	175,000	0.00	175,000	0.00
Maize gluten feed	172		368,834	2.8	383,134	-0.03	272,450	0.13
Extracted soya bean meal (GM)	286		934,560	7.1	770,633	0.33	758,419	0.24
Extracted soya bean meal (NGM)	326		743,008	5.6	743,008	0.00	743,008	0.00
Soya hulls	139		66,189	0.5	33,721	0.06	24,474	0.06
Extracted rape meal	197		1,088,123	8.3	976,980	0.22	832,202	0.35
Whole rapeseed	340	80,000	80,000	0.6	80,000	0.00	80,000	0.00
Extracted sunflower meal	170		374,625	2.8	226,313	0.30	223,121	0.21
Field beans	180	100,000	100,000	0.8	100,000	0.00	100,000	0.00
Peas	183	50,000	50,000	0.4	50,000	0.00	50,000	0.00
Extruded pulse/rape	290	60,000	56,593	0.4	56,593	0.00	56,593	0.00
Sugar beet pulp	150		242,387	1.8	188,572	0.11	188,732	0.07
Palm kernel extractions	148		360,057	2.7	361,343	0.00	358,181	0.00
Citrus pulp	139		39,564	0.3	24,745	0.03	46,595	-0.01
Fishmeal	800		23,492	0.2	23,492	0.00	23,492	0.00
Whey powder	720		4,357	0.0	4,357	0.00	4,357	0.00
Fats	Various		196,808	1.5	196,048	0.00	196,049	0.00
Molasses/Molaferm	140		222,351	1.7	222,351	0.00	222,351	0.00
Other			437,927	1.8	443,407	0.00	446,267	0.00
Total			13,165,200	100	13,165,200	100	13,165,200	100

meal (0.35) and additionally maize gluten feed (0.13) replacement increased (0.13). There was a negligible overall impact on cereal replacement but less wheat was used and more barley.

6.2.2. Baseline with 0.77 and 1.00 Mt of wheat DDGS offered and minimum use imposed on rapeseed meal, sugar beet pulp and wheatfeed (Table 8)

In the previous model run, rapeseed meal, sugar beet

pulp, and wheatfeed volumes were reduced when DDGS was offered. These commodities are all home-produced and a more likely scenario is that their price would fall to maintain usage, there being no other markets for these commodities except export. The model was therefore, re-run with a minimum usage ascribed to these commodities. When 0.77 Mt of wheat DDGS were offered it resulted in replacement of soya meal (0.37), maize gluten feed (0.23) and sunflower meal (0.32). Again, less wheat was used (0.28) and more barley (0.23). Increasing DDGS

Table 8. Multimix of total GB feed market (13.2 Mt excludes on-farm straights fed to ruminants)**Run 1 (2)**

	Price	Market limit	Raw material use					
	£/t	t	t	(%)	t	Replacement	t	Replacement
Wheat DDGS	197		275,000		775,000	-1	1,000,000	-1
Barley	152		1,085,038	8.2	1,199,553	-0.23	1,095,273	-0.01
Wheat	161		5,140,867	39.0	4,998,539	0.28	5,054,440	0.12
Oats	125	110,000	100,000	0.8	100,000	0.00	100,000	0.00
Wheatfeed	141	82,500 min	825,420	6.3	825,000	0.00	825,000	0.00
Bakery meal	170	175,000	175,000	1.3	175,000	0.00	175,000	0.00
Confectionary meal	185	175,000	175,000	1.3	175,000	0.00	175,000	0.00
Maize gluten feed	172		368,834	2.8	251,631	0.23	162,431	0.28
Maize gluten meal	580		0	0.0	0	0.00	0	0.00
Extracted soya bean meal (GM)	286		934,560	7.1	751,688	0.37	715,689	0.30
Extracted soya bean meal (NGM)	326		743,008	5.6	743,008	0.00	743,008	0.00
Soya hulls	139		66,189	0.5	53,415	0.03	63,530	0.00
Extracted rapeseed meal	197	1,088,123	1,088,123	8.3	1,088,123	0.00	1,088,123	0.00
Whole rapeseed	340	80,000	80,000	0.6	80,000	0.00	80,000	0.00
Extracted sunflower meal	170		374,625	2.8	216,579	0.32	135,425	0.33
Field beans	180	100,000	100,000	0.8	100,000	0.00	100,000	0.00
Peas	183	50,000	50,000	0.4	50,000	0.00	49,425	0.00
Extruded pulse/rape	290	60,000	56,593	0.4	56,593	0.00	56,593	0.00
Sugar beet pulp	150	240,000 min	242,387	1.8	240,000	0.00	240,000	0.00
Palm kernel extractions	148		360,057	2.7	358,230	0.00	357,335	0.00
Citrus pulp	139		39,564	0.3	41,149	0.00	61,532	-0.03
Fishmeal	800		23,492	0.2	23,492	0.00	23,492	0.00
Whey powder	720		4,357	0.0	4,357	0.00	4,357	0.00
Fats	Various		196,808	0.0	196,048	0.00	196,163	0.00
Molasses/Molaferm	140		222,351	1.7	222,351	0.00	222,654	0.00
Other			437,927		440,444		440,730	
Total			13,165,200		13,165,200		13,165,200	

to 1 Mt resulted in a similar protein replacement (soya meal, 0.30; maize gluten feed, 0.28; sunflower meal, 0.33) but with a smaller influence on cereals with virtually no change to barley usage and a reduction in wheat (0.12).

When 1 Mt of DDGS was offered, only 71 kt featured in pig and 108 kt in poultry. It is evident that wheat DDGS has a greater financial value in ruminant feeds, particularly in higher protein and dairy compounds with a high concentration of digestible fibre (HDF), and in ruminant blends, than it has in monogastric feeds. This is illustrated in Figures 2 and 3. Only a small amount of wheat DDGS

is used in any feeds when priced at £228/t, but as price drops the usage in ruminant feeds increase almost linearly until it reaches around 1 Mt at a price £185/t. At £185/t, the usage in pig and poultry feed is only just starting to increase at around 0.15 Mt. Total usage of DDGS falls linearly with price so the average inclusion rate in the feeds falls by 0.19% per £1/t increase in wheat DDGS price over the price range tested. Offering 775 kt of wheat DDGS resulted in a slight reduction in overall cereal use but a greater use of barley and less wheat. This is heavily dependent upon the relative price of these commodities. Thus with the barley priced at £152/t, barley usage is

Table 9. Multimix of total GB feed market (13.2 Mt excluding on-farm straights)**Run 1 (3)**

	Price	Raw material use				
	£/t	t	t	(%)	t	Replacement
Wheat DDGS - mono	173.5		0		308,106	-1
Wheat DDGS - cattle	197.5		275,000		697,660	
Barley	152		1,090,623	8.3	1,012,453	0.11
Wheat	161		5,135,788	39.0	5,069,203	0.09
Oats	125	110,000	100,000	0.8	100,000	0.00
Wheatfeed	141	82,500 min	825,000	6.3	825,000	0.00
Bakery meal	170	175,000	175,000	1.3	175,000	0.00
Confectionary meal	185	175,000	175,000	1.3	167,638	0.01
Maize gluten feed	172		368,830	2.8	223,582	0.20
Maize gluten meal	580		0	0.0	0	0.00
Extracted soya bean meal (GM)	286		934,417	7.1	711,237	0.31
Extracted soya bean meal (NGM)	326		743,008	5.6	743,008	0.00
Soya hulls	139		66,002	0.5	52,808	0.02
Extracted rapeseed meal	197	1,088,123	1,088,229	8.3	1,088,123	0.00
Whole rapeseed	340	80,000	80,000	0.6	80,000	0.00
Extracted sunflower meal	170		374,405	2.8	165,036	0.29
Field beans	180	100,000	100,000	0.8	100,000	0.00
Peas	183	50,000	50,000	0.4	50,000	0.00
Extruded pulse/rape	290	60,000	56,593	0.4	56,593	0.00
Sugar beet pulp	150	240,000 min	242,515	1.8	240,000	0.00
Palm kernel extractions	148		360,050	2.7	359,809	0.00
Citrus pulp	139		39,601	0.3	53,437	-0.02
Fishmeal	800		23,492	0.2	23,492	0.00
Whey powder	720		4,357	0.0	4,357	0.00
Fats	Various		197,027		196,133	0.00
Molasses/Molaferm	140		222,351	1.7	222,351	0.00
Other			437,912		440,174	
Total			13,165,200		13,165,200	

1.2 Mt and total wheat and barley usage is 6.2 Mt. Reducing the barley price to £150/t increases barley usage to 1.35 Mt, with the total wheat and barley remaining unchanged. However, increasing the barley price to £154/t drops the usage dramatically to 0.70 Mt, and total wheat and barley usage falls to 6.08 Mt. Simplistically, wheat has more energy than barley and therefore has a slightly higher financial value. If the price differential to barley is too high then wheat inclusion falls. This is normally accompanied by a fall in the inclusion rate of wheatfeed, or some other more fibrous ingredient, so that dietary energy levels are maintained. As replacement values are highly dependent upon the relative price of wheat and barley, it is suggested that total cereal replacement should be the major consideration in land-use calculations rather the wheat and barley individually.

6.2.3. Baseline with 1.00 Mt of wheat DDGS offered, minimum use imposed on rapeseed meal, sugar beet pulp and wheatfeed, and a £24/t transport premium on wheat DDGS feed to ruminants (Table 9)

Another consideration is the majority of cattle are concentrated in the West of the country, whilst cereal and monogastric production is concentrated in the East. Thus whilst a local haul of DDGS pellets might cost £5/t to transport, to the SW it could be £20/t. This difference is even greater when the less dense DDGS meal is considered (the output of Ensus is meal) which might be £9/t locally but at an extreme £36/t to the South West.

The model was therefore run with wheat DDGS offered at a nominal £24/t more to ruminants than to monogastrics. Despite this comparatively large price penalty, nearly

70% of the wheat DDGS was still used in ruminant feeds. Replacement still strongly features proteins with soya meal (0.31), sunflower meal (0.29) and maize gluten feed (0.20) being the commodities most influenced. However, with an increase in DDGS in monogastric feeds results in a replacement of both wheat (0.09) and barley (0.11).

7. Discussion

Table 10. Calculation of crude protein and metabolisable energy of wheat DDGS from replacement factors (Table 8, for 0.77 Mt wheat DDGS)

	Protein (%)	ME (MJ/kg)	Inclusion (%)
Extracted soya bean meal	48	12.3	0.37
Extracted sunflower meal	31	8.7	0.32
Maize gluten feed	20	11.5	0.23
Wheat	11	11.9	0.29
Soya hulls	12	10	0.03
Total nutrient	35.5	13.61	1.23
Wheat DDGS	33	11.2	1.00
Citrus pulp	6	11.85	0.00
Barley	10	11.35	0.23
Total nutrient	35.3	13.80	1.23

Table 11. Calculation of crude protein and metabolisable energy of wheat DDGS from replacement factors (Table 8, for 1 Mt wheat DDGS).

	Protein (%)	ME (MJ/kg)	Inclusion (%)
Extracted soya bean meal	48	12.3	0.302
Extracted sunflower meal	31	8.7	0.33
Maize gluten feed	20	11.5	0.285
Wheat	11	11.9	0.119
Total nutrient	31.7	11.3	1.036
Wheat DDGS	33	11.2	1
Citrus pulp	6	11.85	0.022
Barley	10	11.35	0.014
Total nutrient	33.3	11.6	1.036

7.1. Wheat DDGS replacement in the Great British feed market

7.1.1. The influence of DDGS tonnage and the proportion of ruminant and monogastric feed production

It is evident that in the GB market wheat DDGS replacement cannot simply be estimated as a proportion of cereals and soya. Wheat DDGS has a much greater financial value in ruminant feeds compared to those for

Table 12. The influence of a large volume of wheat DDGS on raw material replacement rate by species group in the GB market.

	Pig	Poultry	Ruminant	Total	Pig and poultry
Wheat DDGS (t)	338110	336623	951364	1626097	674733
Barley	0.96	0.21	0.10	0.30	0.59
Wheat	-0.71	0.71	-0.05	-0.03	0.00
Oats	0.05	0.00	-0.02	0.00	0.03
Wheatfeed	0.36	-0.02	0.01	0.08	0.17
Maize gluten feed	0.00	0.00	0.22	0.13	0.00
Extracted soya bean meal (GM)	0.25	0.19	0.28	0.26	0.22
Extracted soya bean meal (NGM)	0.00	0.18	0.00	0.04	0.09
Soya hulls	0.00	0.00	0.00	0.00	0.00
Whole rape	0.00	0.00	0.00	0.00	0.00
Extracted rape seed meal	-0.12	-0.37	0.19	0.01	-0.25
Extracted sunflower meal	0.08	0.20	0.21	0.18	0.14
Palm kernel extractions	0.00	0.00	0.21	0.12	0.00
Field beans	0.02	0.00	-0.01	0.00	0.01
Peas	0.00	0.00	0.00	0.00	0.00
Extruded pulse/rape	0.00	-0.01	0.00	0.00	-0.01
Sugar beet pulp	0.00	0.00	0.00	0.00	0.00
Citrus pulp	0.00	0.00	-0.11	-0.06	0.00
Bakery	0.15	0.08	-0.08	0.00	0.12
Confectionary	-0.03	-0.09	0.05	0.00	-0.06
Other	-0.01	-0.09	0.00	-0.02	-0.05
Total	1.00	1.00	1.00	1.00	1.00
Total cereals	0.30	0.92	0.04	0.28	0.61
Total soy	0.25	0.37	0.28	0.29	0.31

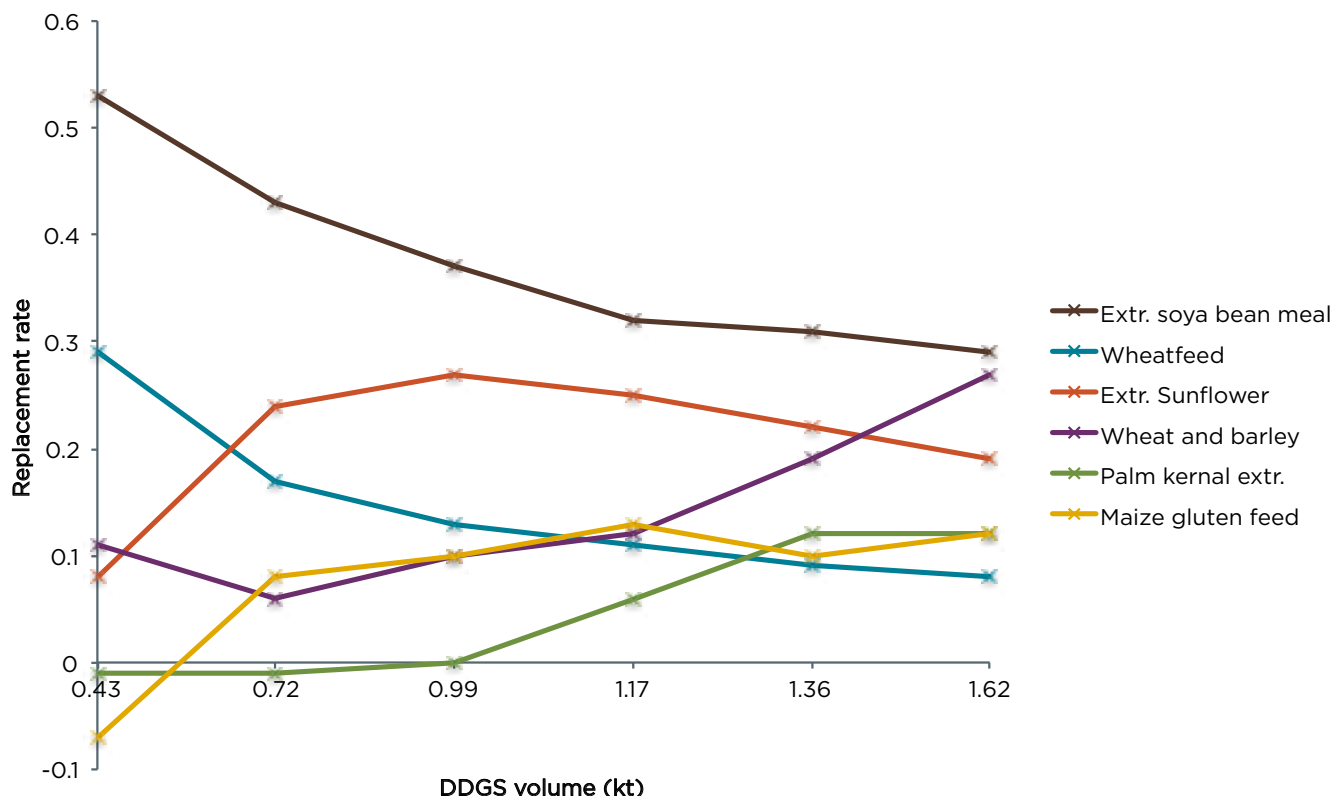


Figure 4. The influence of DDGS volume on replacement rate of selected feed ingredients in the GB feed market

monogastric animals. The most expensive nutrient constraints in most ruminant feeds are protein and metabolisable energy. Therefore any substitution should give a similar protein and energy to wheat DDGS and this is indeed the case (Tables 10 and 11). Wheat DDGS in ruminant feeds largely replaces soya, sunflower and maize gluten meal with some balancing with small quantities of cereals and fibrous ingredients. However in monogastric feeds the most expensive constraints are energy and amino acids. The energy level of wheat DDGS is “moderate” for monogastrics whilst the amino acid concentration is poor which together limit its relative financial value.

The influence of the species being fed is shown in more detail in Table 12. In this evaluation wheat DDGS was offered at a low price to ensure that it was used in monogastric feeds. In total 1.62 Mt of wheat DDGS was used, 0.67 Mt of this in pig and poultry feeds. In ruminant feeds replacement was again dominated by soya meal and mid-proteins, with little impact on cereal usage. In contrast, wheat DDGS in pig and poultry feed replaced mainly cereals and soya, and additionally rape meal was preferred to sunflower meal and wheatfeed. The comparison between wheat DDGS and rapeseed meal is of interest. Wheat DDGS has a similar protein to rape seed meal but has a higher energy and digestible undegradable protein. Wheat DDGS therefore has a greater financial value in ruminant feeds than rapeseed meal. However, wheat DDGS has a much poorer concentration of amino acids, which are essential in monogastrics, such that in most feed specifications and with current high soya bean meal prices, wheat DDGS is worth less than rapeseed meal in pig and poultry feeds.

The greater the quantity of a commodity offered, at an attractive price, the greater the number of feed

specifications that will use it. Initially in this GB model, dairy feeds of 20-22% protein use DDGS, then as price falls, is included in dairy blends, other ruminant feeds, and finally as these ruminant markets become increasingly saturated, the DDGS spills over into monogastric feeds. For example, wheat DDGS is very attractive to dairy 20 HDF (high digestible fibre) in particular as this feed is not only on minimum energy and protein constraints, but additionally was on minimum oil and NDF, nutrients that wheat DDGS has in relatively high concentration. Thus 4 nutrient constraints are in part satisfied in this feed by wheat DDGS which explains its high value. It is the “degree of fit” of the wheat DDGS analysis, and its price, compared to the other commodities offered, that determines where it is utilised.

The influence of increasing volumes of wheat DDGS on raw material replacement market in the GB market is shown in Table 13 and Figure 4. Trends in replacement values as DDGS supply increases are not linear but as noted earlier, increasing DDGS volume reduces soya and mid-protein replacement and increases that of cereals.

7.1.2. Modelling a feed market rather than an individual feed specification.

Another important consideration is that when a new commodity, or increasing quantities of an existing one, is offered to a feed market its replacement can only be estimated by looking at the entire market rather than specific feeds or species groups. For example, returning to the Dairy 20 HDF example discussed above, the major raw material replaced in this feed when modelling total GB feed was field beans (0.88). Total field bean tonnage was restricted in the model to 100,000t representing domestic

availability. That field beans are the main replacement in this feed will be in part due to their limited supply, and also their higher value in one of the other 50 specifications under consideration.

7.1.3. The evolution of feed specifications

Feed specifications evolve with commodity prices and availability. For example the nutrient density of a pig finisher can be reduced, with a poorer feed conversion resulting, as long as total feed costs are reduced. At some stage though appetite becomes limiting and growth is reduced, increasing fixed costs. Such a strategy has been recently employed in the UK as barley and wheatfeed were relatively inexpensive compared to wheat. Similarly in the US, corn DDGS has been inexpensive and feed specifications have been reduced in nutrient density to accommodate it. The value of wheat DDGS is so much higher in ruminant feeds under GB conditions, that, even if monogastric feeds are reduced in specification, the majority of wheat DDGS is still likely to be use in ruminant

feeds unless volumes become very significant (> 1 Mt). Further reductions in nutrient density also apply to the ruminant market. For example, rather than feeding a dairy 38% protein blend it may be more economic to feed more of a dairy 35% blend. This would result in a fall in soya replacement and an increased required for DDGS in the ruminant sector.

7.1.4. Reducing soya bean meal, and maximising wheat DDGS usage, and the influence of crystalline amino acid prices and availability

In order to determine how a low soya usage could be achieved in GB, with current feed specifications, the model was run with the price of soya doubled and an unlimited volume of wheat DDGS at a low price of £150/t. The quantity of wheat DDGS utilised was 1.7 Mt (12.9%) and soya bean usage fell from 1.67 Mt (Table 8) to 1.10 Mt with poultry feeds using 0.93 Mt, pig 0.12 Mt and ruminant 0.05 Mt. Broiler and turkey feeds in particular, as currently specified, are heavily reliant upon soya bean meal.

Table 13. Replacement rate of wheat DDGS in the GB market at various prices assuming no limitations to DDGS supply

Wheat DDGS (£/t)	220	200	180	170	160	150
Wheat DDGS (t)	434,105	723,857	985,944	1,168,495	1,356,770	1,616,697
Barley	0.63	-0.02	0.11	0.20	0.26	0.28
Wheat	-0.52	0.08	-0.01	-0.08	-0.07	-0.02
Wheatfeed	0.29	0.17	0.13	0.11	0.09	0.08
Maize gluten feed	-0.07	0.08	0.13	0.13	0.10	0.12
Extracted soya bean meal (GM)	0.53	0.43	0.37	0.32	0.31	0.26
Extracted soya bean meal (NGM)	0.00	0.00	0.00	0.00	0.00	0.03
Soya hulls	0.02	0.03	0.01	0.01	0.01	0.00
Extracted rapeseed meal	0.02	0.01	0.01	0.01	0.01	0.01
Extracted sunflower meal	0.08	0.24	0.27	0.25	0.22	0.19
Palm kernal extractions	-0.01	-0.01	0.00	0.06	0.12	0.12
Field beans	0.00	0.00	0.00	0.00	0.00	0.00
Extruded pulse/rape	0.00	0.00	0.00	0.00	0.00	0.00
Sugar beet pulp	0.00	0.00	0.00	0.00	0.00	0.00
Citrus pulp	0.01	-0.02	-0.02	-0.04	-0.06	-0.05
Bakery	0.00	0.00	0.00	0.02	0.00	0.00
Other	0.02	0.01	0.01	0.01	0.00	-0.02
Wheat and barley	0.11	0.06	0.10	0.12	0.19	0.27

Model run with minimum 825 kt wheatfeed, 1088kt of rapeseed meal, 240 kt of sugar beet pulp.

Table 14. Industrial compound feed production in the EU in 2009 (kt and %)

	DE	FR	IT	NL	BE	UK	IE	DK	ES	PT	AT	SE	FI	EU 15*
Cattle	5876	4927	3480	3364	1097	4799	2131	997	6740	805	593	915	590	36114
Pigs	8923	5915	3180	5936	3580	1497	633	2867	9500	955	232	377	341	43936
Poultry	5169	8470	5445	3623	1326	6230	486	550	4400	1380	446	534	285	38344
Others	861	1924	1725	1185	182	1281	406	174	909	270	35	141	60	9373
Total	20829	21236	13830	14108	6185	13807	3656	4588	21549	3410	1306	1967	1276	127767
	CY	CZ	EE	HU	LV	LT	PL	SK	SI	BU	RO	EU -12**	EU-27	
Cattle	111	502	40	530	38	32	652	206	95	76	130	2412	38526	
Pigs	13	929	140	1580	111	71	1477	214	110	234	1400	6279	50215	
Poultry	62	1039	48	1755	159	245	4807	223	260	541	1530	10669	49013	
Others	110	370	2	205	17	16	319	12	12	23	12	1098	10471	
Total	296	2840	230	4070	325	364	7255	655	477	874	3072	20458	148225	

	DE	FR	IT	NL	BE	UK	IE	DK	ES	PT	AT	SE	FI	EU 15*
Cattle	28.2	23.2	25.2	23.8	17.7	34.8	58.3	21.7	31.3	23.6	45.4	46.5	46.2	28.3
Pigs	42.8	27.9	23.0	42.1	57.9	10.8	17.3	62.5	44.1	28.0	17.8	19.2	26.7	34.4
Poultry	24.8	39.9	39.4	25.7	21.4	45.1	13.3	12.0	20.4	40.5	34.2	27.1	22.3	30.0
Others	4.1	9.1	12.5	8.4	2.9	9.3	11.1	3.8	4.2	7.9	2.7	7.2	4.7	7.3
Total		100	100	100.0	100.	100	100	100	100	100	100	100	100	100
	CY	CZ	EE	HU	LV	LT	PL	SK	SI	BU	RO	EU -12**	EU-27	
Cattle	37.5	17.7	17.4	13.0	11.7	8.8	9.0	31.5	19.9	8.7	4.2	11.8	26.0	
Pigs	4.4	32.7	60.9	38.8	34.2	19.5	20.4	32.7	23.1	26.8	45.6	30.7	33.9	
Poultry	20.9	36.6	20.9	43.1	48.9	67.3	66.3	34.0	54.5	61.9	49.8	52.2	33.1	
Others	37.2	13.0	0.9	5.0	5.2	4.4	4.4	1.8	2.5	2.6	0.4	5.4	7.1	
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	

* Without Luxembourg and Greece;

** without Malta

***Without Luxembourg, Greece and Malta

FEFAC, 2009

In the above formulations crystalline amino acids (lysine, methionine, threonine, tryptophan and valine) were all offered which is normal commercial practice. With the high price of soya in comparison to cereals these amino acids are attractive and feature strongly in the formulations. Their inclusion rate is normally limited by the next limiting amino acid. Thus for example in the broiler feeds

arginine is limiting and soya is used in part to satisfy this constraint.

To determine if higher quantities of wheat DDGS could be used, and soya bean meal usage further reduced, the model was re-run halving the price of the existing crystalline amino acids and additionally assuming that crystalline

isoleucine and arginine were available at a nominal price of £5000/t. Wheat DDGS usage increased only slightly to 1.77 Mt but total soya usage fell further to 0.63 Mt, with poultry soya usage almost halving to 0.45 Mt. Considerable quantities of crystalline amino acids were used (lysine 44 kt, methionine 16.9 kt, threonine 14.6 kt, tryptophan 1.9 kt, valine 5.2 kt, isoleucine 6.2 kt, arginine 10.3 kt). Thus, should a greater range of crystalline amino acids become available at an attractive price then there is a much greater impact on soya usage than on that of wheat DDGS.

7.1.5. Wheat DDGS replacement in the EU

It is our belief that this model accurately reflects the likely impact of wheat DDGS on the GB feed market. That the wheat DDGS produced to date by Ensus has almost entirely been used in ruminant feeds adds weight to the conclusion that the value of wheat DDGS is higher in ruminant feeds and that this will be a major influence on commodity replacement rates. Unfortunately, it is not possible simply to run the model for the EU as a whole. The basic model could be adapted for specific countries, but local knowledge would be essential to do so with any degree of accuracy, particularly with regard to the feed specifications and tonnage allocation. Nevertheless, it is clear that both the range of commodities available and the species being fed are major determinants of wheat DDGS replacement and thus are worth examining.

EU compound feed production is shown in Table 14 and totals in excess of 148 Mt, similar in size to the USA (149 Mt). Pig feed represents 33.9% of total EU compound feed production, poultry 33.1% and cattle 26%. GB feed production, using the same dataset, is 10.8% pig, 45.1% poultry and 34.8% cattle and so has a greater bias towards cattle and poultry feed than the EU as a whole. The EU cattle compound production is 38.5 Mt and assuming a 20% DDGS inclusion rate, suggests an EU cattle compound market potential of 7.7 Mt. This is compound production and excludes the potential for feeding wheat DDGS direct to cattle on-farm. EU DDGS production was estimated at 4 Mt in 2009 (epure.org) whilst imports of DDGS into the EU have fallen from 779 kt in 2003 to 206kt in 2009. Thus the current DDGS supply is a little over 60% of that required by EU compound cattle feed. Some estimates suggest 110 Mt of cereals could be used for bioethanol in the EU by 2020 which would generate, at 35%, approximately 38.5 Mt of EU DDGS (Pinkney, 2008). This would represent 26% of all EU compound feed production.

The average composition of compound feed in the EU is shown in Table 15 and is not dissimilar to that used in GB (Table 1) although the data does not differentiate oilcakes, meals and cereals into individual commodities. Southern Europe is more maize based whereas the north is dominated by wheat and barley. Maize is higher in energy and lower in protein than wheat and barley but the differences are insufficient to have a marked influence on replacement rates. There is current debate concerning the re-introduction of meat and bone meal; this could have a significant influence on replacement rates in the future.

However neither commodity use nor the species profile in the EU appear sufficiently different to the GB model to invalidate the major conclusion of this paper in that wheat DDGS will preferentially be used in ruminant feeds.

However, whilst the EU overall is a major importer of soya meal, it is not a major importer of mid-proteins such as sunflower and maize gluten meal and in this respect it differs from GB. Furthermore, domestically produced sunflower meal is available in the south of the EU, and as is the case with rapeseed meal in GB, will find a price at which it continues to be utilised as DDGS availability increases. Thus the DDGS replacement rates suggested for GB will not be applicable to the EU as a whole and each country within the EU is likely to have a unique solution.

Table 15. Compound feed raw material usage in the EU (FEFAC, 2009)

	kt	%
Cereals	71480	48.2
Tapioca	758	0.5
Food co-products	17139	11.6
Oils and fats	2187	1.5
Oilcakes and meals	40829	27.5
Pulses	1793	1.2
Animal meals	576	0.4
Dairy products	1149	0.8
Dried forage	1995	1.3
Minerals/vitamins	4285	2.9
Others	6034	4.1
Total	148225	100.0

8. References

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Appendix: Estimations of feed market size, feed specifications and tonnage allocation

It is the intention of the feed formulation model to determine the likely consequences of the introduction of 2 Mt wheat DDGS under a number of cost/supply scenarios. In order to do so the UK animal feed market needs to be defined and feed specifications allocated to each major market sector. Defra (Department of Environmental Food and Rural Affairs- www.defra.gov.uk) publishes many of the statistics used in this document but inevitably there are additionally a number of assumptions made.

The UK pig feed market.

Defra show GB retail sales in 2010 as follows.

Table A. GB animal feed retail sales in 2010

Pig	Defra GB retail sales (kt)	%
Starter	58.1	4.0
Link	68.2	4.7
Grower	328	22.8
Finishing	572.5	39.8
Breeding	393.9	27.4
Protein concentrates	16.7	1.2
Total	1437.4	100

Pig slaughtering and sow census data suggest a GB feed total market of around 2.49 Mt of feed (using typical pig performance data) so that approximately 60% of the market is supplied by compound feed and 43% mixed on-farm. Terminology such as "link", "grower" and "finisher" have no defined weight ranges and the meaning changes regionally. Percentage tonnage allocation has therefore been redefined against the feed specifications used in the model. There is a bias in the percentage of feed home-mixed in that outdoor sows (circa 35% of the total) are fed rolls (16-20 mm pellets) and these cannot be manufactured by homemixers. Further starter feed is virtually all manufactured in specialist starter feed mills.

The following feed specifications and tonnages were therefore allocated to represent the GB 2.5 Mt pig feed market in 2010.

Table B. Feed specifications and tonnages for pig feed market

Model Feed Specification	Compound GB (kt)	Homemix GB (kt)	Total (kt)
Starter	58.1		58.1
Grower	161.8	156.0	317.8
Finisher 1	322.8	311.2	634.0
Finisher 2	484.2	466.8	950.9
Lactating sow (40%)	157.6	55.1	212.7
Dry sow feed (60%)	161.3	82.7	244.0
Outdoor rolls	75	0	75.0
Total	1420.7	1071.7	2492.4

Home-mixed feed is largely meal whereas compounded feed is largely pellets. Pellet specifications are different in that pellet quality cannot be maintained with barley levels in excess of about 30% and there is a higher minimum requirement for oil as a die lubricant.

Retail compound feed sales in Northern Ireland are 150 kt/annum and homemixing is estimated at 30% giving a total market of approximately 214 kt and a total UK pig feed market of 2.706 Mt.

The UK poultry feed market

Defra record GB retail feed sales and the feed produced by integrated companies and this is shown for 2010 in the following table (kt). The poultry feed market is almost 2.5 times that of the pig and together the GB monogastric sector uses about 8.4 Mt of feed/annum.

Table C. Retail poultry feed sales, poultry feed production by integrated companies (2010)

Poultry	Compound (kt)	Integrated (kt)	Total (kt)
Chick/rearing	160.9		160.9
Layer	1018.3	214.2	1232.5
Broiler	1199.2	2094.5	3293.7
Breeding/rearing	240.7	152.9	393.6
Turkey	188.1	313.6	501.7
Other poultry	313.6		313.6
Protein concs	1.4		1.4
Total	3122.2	2775.2	5897.4

"Other poultry" includes duck, game and whole wheat (whole wheat feeding is common in the UK in broilers and turkeys). It is estimated from slaughtering that the duck feed market is circa 105 kt. There are no reliable statistics for game feed; an estimate of 75 kt has been used. Duck and game feed are closest in specification to turkey feed and these 180 kt have thus been allocated accordingly to the turkey tonnage. This leaves proximately 133.6 kt of whole wheat added to broiler and turkey feeds sold

for retail sale. It is understood that integrated companies include whole wheat when added at the mill into broiler feed sales. It is estimated that a further 5% of whole wheat is added on farm to integrated broiler tonnage.

The following 18 feed specifications and tonnages were therefore allocated to represent the 6 Mt GB poultry feed market in 2010.

Table D. Feed specifications and tonnages for poultry feed market

Model Feed specification	GB tonnage allocation	“Other tonnage” allocation	Model allocation
	(kt)	(kt)	(kt)
Broiler starter	187		187
Broiler grower	936		936
Broiler finisher/withdraw	2171		2171
Total broiler	3294		3294
Turkey starter	68.8	24.7	93
Turkey grower 1	90.9	32.6	124
Turkey grower 2	116.1	41.6	158
Turkey finisher 1	130.9	47.0	178
Turkey finisher 2	95.0	34.1	129
Total turkey	501.7	180.0	682
Layer 1	456.0		456
Layer 2	468.4		468
Layer 3	308.1		308
Total layers	1232.5		1233
Broiler Breed starter	7.9		8
Broiler Breed grower	78.7		79
Broiler Breeder	307.0		307
Total broiler breeders	393.6		394
Layer starter	11.3		11
Layer chick	54.7		55
Layer grower	94.9		95
Total layer breeder	160.9		161
Other - game/duck	180		
Whole wheat (Comp)	133.6	133.6	134
Whole wheat (integ)	104.7		105
Total	6001		6001