By-products from ethanol production – the forgotten part of the equation

Jensen, Hans Grinsted; Björnsson, Andreas Haldrup; Lind, Kim Martin Hjorth

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Jensen, H. G., Björnsson, A. H., & Lind, K. M. H. (2013). By-products from ethanol production – the forgotten part of the equation: possibilities and challenges. Department of Food and Resource Economics, University of Copenhagen. IFRO Report, No. 219

DEPARTMENT OF FOOD AND RESOURCE ECONOMICS
UNIVERSITY OF COPENHAGEN

IFRO Report

By-products from ethanol production – the forgotten part of the equation

Possibilities and challenges

Hans Grinsted Jensen
Andreas H. Björnsson
Kim Martin Lind

219

IFRO Report 219

By-products from ethanol production – the forgotten part of the equation:
Possibilities and challenges

Authors: Hans Grinsted Jensen, Andreas H. Björnsson, Kim Martin Lind

Published June 2013

This paper was commissioned by Novozymes A/S. The authors acknowledge the cooperation with Anders Lyngaa Kristoffersen, Manager Public Affairs, Region Europe, Novozymes A/S, who provided helpful comments on earlier drafts of this paper. Any views and opinions expressed in this paper are entirely the authors' own.

IFRO Report is a continuation of the series FOI Report that was published by the Institute of Food and Resource Economics.

ISBN: 978-87-92591-33-3

Department of Food and Resource Economics
University of Copenhagen
Rolighedsvej 25
DK 1958 Frederiksberg
www.ifro.ku.dk/english

Content

Summary of findings

Conventional bioethanol is produced from starch based feedstocks either via dry or wet milling, using typically maize or wheat. One by-product from bioethanol production is dried distiller's grain with solubles (DDGS), which has proven to be a valuable feed commodity for animal husbandry. Particularly, DDGS replaces expensive protein feed at a competitive price for farmers, which has hitherto led to a rapidly increasing market for distiller's grain with solubles in the US, who is by far the largest producer of grain-based bioethanol in the world. The US also exports DDGS since it has a long shelf-life and can therefore be shipped overseas. Exports of DDGS from the US are increasingly taking place with Asia but also Europe and South-America as international destinations.

Researchers are still examining how much DDGS can be added to animal feed diets. Up to 20 -30 % depending on animal type is recommended; however, there is on-going research and development in improvements in the product, which may increase this level even further. The majority of distiller's grain with solubles is consumed domestically in the countries where it is produced, but exports of DDGS are projected to increase as bioethanol production expands.

Studies[23] [24] indicate that the price of DDGS in the US follows the corn price and is roughly at the same price level, even though protein contents in distiller's grain with solubles are higher than for cereals. With this price relationship, feed diets incorporating DDGS produce cost savings for farmers. An example for a Danish dairy farm shows that with this price relationship profits would increase by around 5 % per dairy cow if DDGS is included in the fodder plan, accounting for roughly 10 % of the energy content. Given that the US exports large amounts of DDGS it would be expected that the price level in Denmark would be highly influenced by US export prices, if Danish farmers adopt DDGS in their feed rations.

One major barrier for increased acceptance of DDGS by potential buyers/farmers is the absence of a standard for the product. Pre-tested and pre-blended food diets with DDGS could lead to greater certainty of effects and acceptance by farmers. This could presumably increase the price of DDGS from current levels, which is lower than the feed value appears to suggest, due to uncertainty around the product as well as varying quality of DDGS.

The stated goals by the US and the EU of increasing bioethanol production and use in the energy supply have been criticised heavily for using land that could otherwise produce food. The use of the bioethanol by-product such as DDGS mitigates the land use considerably, which should be taken into account when considering the overall effects of bioethanol production.

When DDGS replaces traditional animal feed, the amount of agricultural land required to grow traditional feed crops is reduced. Several studies attempt to estimate the effect of land reduction due to using DDGS as feed. The estimates vary considerably dependent upon the assumptions and models used.

One study[22] based on yields in North Western Europe suggests that the direct effect of DDGS reduces the amount of land required for bioethanol production by 94 % directly. This means that one hectare of grains processed through a bioethanol plant would produce enough by-products/feed so that the grown area with feed elsewhere can be reduced by 0.94 hectares. If all other agricultural land use in the world remains unchanged (except land used for bioethanol and feed crops) then the total agricultural areas in the world would have to increase by a mere 0.06 hectare for every hectare of grains grown for biofuel production. Another study[32] focusing on corn based bioethanol production in the United States concludes that the direct effect of DDGS reduces the amount of land required by bioethanol production with around 71 % in the US.

Clearly, if one hectare diverted to biofuel production nearly reduces the required amount of land used to grow feed by one hectare in some regions of the world via the feed effect of DDGS then the net effect on other land using productions as well as food prices should be minimal. However, if the feed effect of DDGS from one hectare used for biofuel production reduces the feed area by less than one hectare then there will be some indirect effect on land uses through increased demand for land, in for example the US. This could lead to changing cropping patterns in the US affecting the rest of the world through changes to US trade volumes.

A study[35] which takes these direct and indirect land use changes into account use a comprehensive global model. In this study the direct effect of using DDGS as animal feed was estimated to reduce the required feed area by 31%. Moreover, the study also highlighted the fact that the increased demand for land due to increased bioethanol production would raise the price of land and thereby non-food and food prices. These increased prices would reduce the global demand for non-food and food products, by which the amount of land required to grow these products, would be reduced. When these land use changes are taken into consideration then one hectare of land used for bioethanol is predicted to require a little more than 1/4 of a hectare of new agricultural land, which would have to be converted from other uses. This comprehensive estimate has been highlighted in a report from the EU-Commission as the most realistic estimate of global land use change due to an expansion of US bioethanol production.

Summing up, the studies on land use effects of bioethanol production show albeit with variations that the land required for bioethanol production is substantially reduced by the feed effect of the by-product DDGS. The impact estimates of bioethanol production on other parts of the economy depend, however, upon the assumptions and models applied. When one hectare used in bioethanol production result in by-products corresponding to an area of less than one hectare of feed crops, a comprehensive model estimating the effects of land price changes is needed. The lower the direct land use effect of the feed value of DDGS is, the higher is the impact upon the rest of the economy including land and food prices.

The introduction of DDGS into the market for feed adds about 25 % to the revenue of a bioethanol plant, which contributes to make investments in this type of energy production more profitable and could thereby help promote greater energy self-sufficiency. Farmers using DDGS in their feed diets appear to have lower costs relative to traditional feed diets at current prices. These cost savings are based on estimates of how much soy bean meal and cereal DDGS replaces (substitution rates). However, substitution rate estimates vary considerably in the literature.

1. Introduction

Energy supply, energy independency and transformation of the economy away from fossil fuel based supplies towards more renewable forms of energy have been high on the political agenda for quite a while. One result of the public and political debate concerning energy is the establishment of targets for bioenergy and in particular fuel produced from agricultural products. This has led to countries with large agricultural production like Brazil and the USA to implement various bioethanol support schemes and they have achieved substantial production levels. On the other hand, the EU although having formulated ambitions supporting bioethanol production such as a requirement of 10 % renewable energy in all transport fuel by 2020 has so far not taken concrete steps towards ensuring production capacity or financial support. Instead, the EU has left the member states with the responsibility of choosing the means of achieving the stated goal.

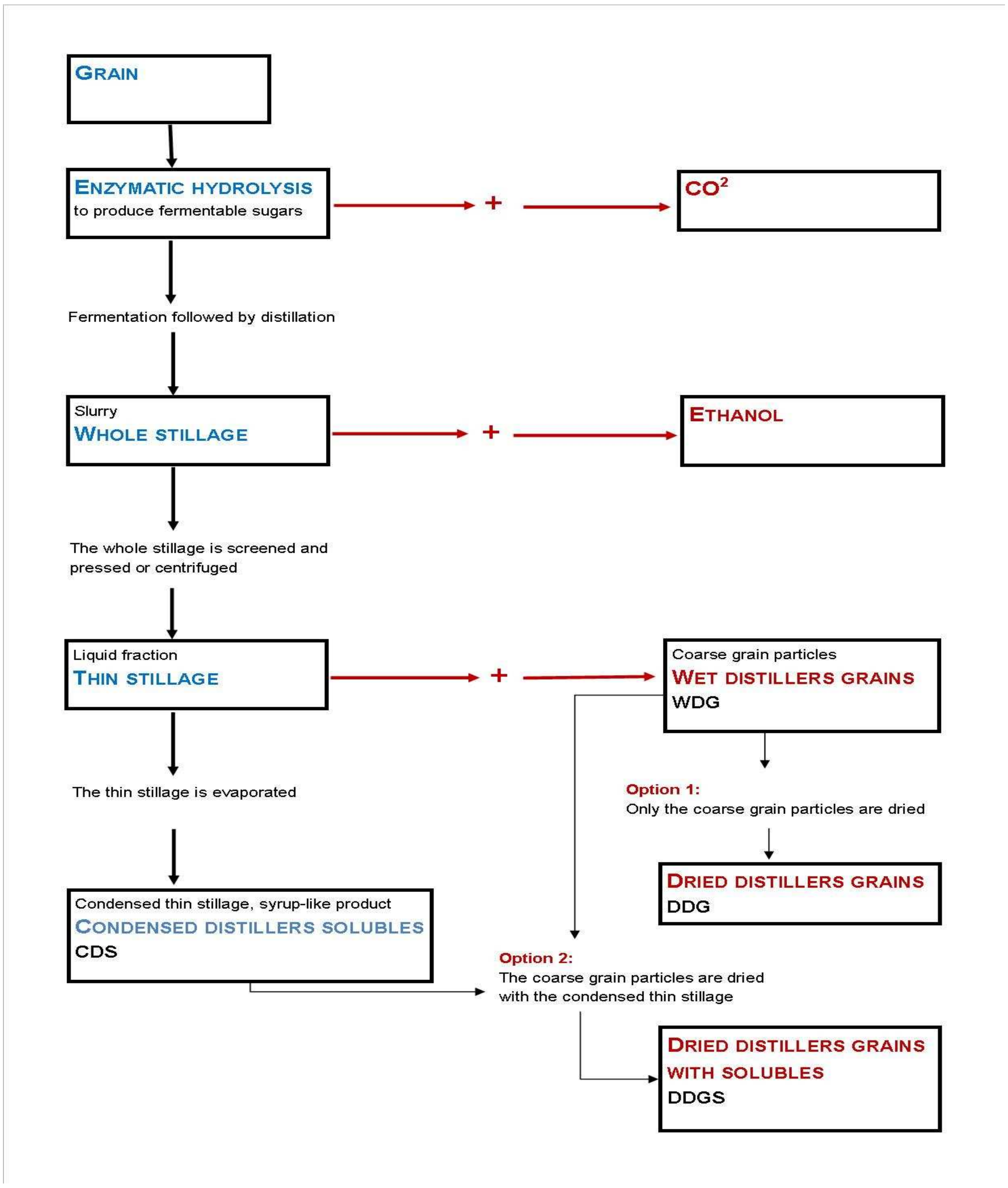
The need to decrease dependency on fossil fuels, climate considerations and energy security issues have been put forward as arguments in favour of furthering bioethanol production. However, opponents of bioethanol have in turn argued that using agricultural land to produce transport fuel is detrimental to the production of crops for food and may lead to higher food prices. Indeed, this debate has been quite heated often with little moderation as for instance when a UN representative denounced biofuel production as a “crime against humanity”[1].

In recent years, the production of conventional bioethanol (also called first generation ethanol) has increased, raising the demand for crops for energy (typically maize and wheat). This higher demand for bioethanol increases the area of starch rich crops cultivated on arable land which can lead to direct land use changes (land needed to produce the crop for the bioethanol production) and indirect land-use change (noticeable induced land use changes at other geographical locations for example deforestation). However, conventional bioethanol production results in several products of which a by-product called DDGS (Dried Distillers Grains with Solubles) can substitute animal feed crops elsewhere. Hence, the net land use for bioethanol crops is reduced and the sale of animal feed in the form of DDGS becomes important for the profitability of bioethanol production plants as farmers become more aware of this new animal feed product. The effect of the feed use of DDGS is, therefore, lowering demand for agricultural land elsewhere, which has been somewhat neglected in the debate concerning bioethanol production. This note attempts to nuance this debate and bring forth some aspects of bioethanol production that have hitherto not been given much attention.

2. What is DDGS and how is it used

Conventional bioethanol is produced from starch based feedstock either via dry or wet milling, using typically maize or wheat. Figure 1 shows the process of converting grains into ethanol and the by-products resulting from the production process, which are utilised as a substitute in livestock diets for both soy bean meal and energy rich components such as wheat or maize.

Figure 1. Flow chart of the DDGS-process



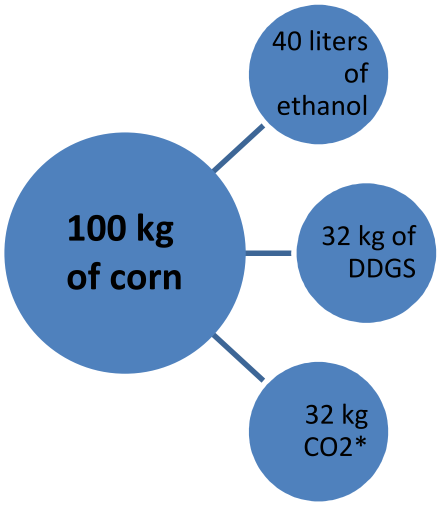
The by-products of bioethanol production are composed of a solid fraction consisting of coarse grain particles known as wet distillers grains (WDG) and a liquid fraction in the form of a thin stillage. The thin silage can be condensed to a syrup-like product called condensed distillers solubles (CDS) and a further drying of WDG produces the by-product dried distillers grains (DDG). The focal point of this note is the blended by-products dried DGS (DDGS) which is produced by combining condensed thin silage (CDS) with coarse grain particles (WDG).

Normally, the primary by-product is wet DGS (WDGS) with a moisture level of 65-69 %. This can be dried into dried DGS (DDGS), with moisture levels 8-12 %[2]. WDGS has a shelf life of 5 to 7 days under normal storage conditions[3], and due to its higher density and weight also results in increased transportation costs relative to DDGS. Therefore, WDGS is rarely exported, but used in the proximity of the production site, normally a radius of about 100 miles[4]. Consequently, DDGS is more relevant to a larger range of potential buyers as DDGS has a longer shelf life and can be exported. Furthermore, DDGS has an increasingly larger production base since the majority of new ethanol producers are establishing dry milling facilities[4].

In the dry milling process, 100 kg of corn results in 40.2 litres of ethanol, 32.3 kg of DDGS and 32.3 kg CO_2[5], as illustrated in figure 2.

Thus there is a substantial production of DDGS, corresponding to a third of the feedstock used in bioethanol production which is supplying an increasing amount of animal feed. This has often been overlooked in the heated debate about conventional biofuels, where there has been a tendency to only look at resources used directly in ethanol production and to overlook the substantial production of DDGS.

Figure 2. **Dry milling process products**



2.1 DDGS used as animal feed

The US Department of Agriculture has undertaken several studies of DGS for use as feed and the potential for substituting particularly corn and soy bean meal. A report from USDA[6] summarises the work and analyses done in this field, where the amount of corn or soybean substituted by DGS depends upon the requirements of different animal types as well as the composition of diets.

DGS is considered a mid-protein feed that offers the same or greater energy as corn but contains less protein than soy bean meal. Ruminant animals, such as beef and dairy cattle, can use DGS more readily than monogastric animals, such as hogs and poultry. Furthermore, DGS have a higher content of calcium, phosphorus and sulphur relative to corn, thereby reducing need for supplements in feed diets. The nutritional contents in DGS needs to be considered when determining the amount used in feed diets, also called the inclusion level, so as not to produce feed diets with too high contents of specific nutrients.

A study by Schingoethe[5] finds that DDGS is a good source of energy and protein for **beef cattle** in all phases of productions. Most of the starch in corn is converted to ethanol during the fermentation process thus fat and fiber concentrations in DDGS are increased by a factor of three relative to corn.

Experimental studies have used feed diets including up to 40 % DDGS with excellent growth performance[7, 8, 9] and with no change in quality or sensory characteristics, although usually 20-30 % is applied in actual feed diets.

DDGS provide a source of protein, fat, phosphorus and energy for **dairy cattle** and provide a highly digestible fibre source that reduces digestive upset more effectively than corn[10]. Feeding DDGS to dairy cattle, where feed diets including up to 20 % DDGS have shown that milk productions is as high as or higher when DDGS replaced a portion of the ground corn and soybean meal in the diets[8].

DDGS can be used in gestation, lactation, nursery, growing and finishing diets for **swine**[11]. Swine, however, cannot efficiently digest the fibre in DDGS and the corn oil present in DDGS can potentially affect meat quality. DDGS can be fed to gestating sows at a level of up to 50 % of the feed diet with nonnegative effects on the animals[12]. For lactating sows the feed diet levels range from 15-30 % according to Stein[11]. For nursery pigs the inclusion rate in feed diets is reduced to 7.5 %[11], although other studies find higher rates. For grow-finish pigs up to 30 % in feed diets is found not to affect growth or quality.

For **poultry** the inclusion rates are reduced due to the high level of fibre, and other characteristics of DDGS[13]. Laying hens are not affected in egg production, egg weight, feed consumption or utilisation with up to 15 % DDGS in feed diets[14]. Feeding high levels of DDGS to broilers are not recommended due to high fibre content and low amino acid digestibility of DDGS. In starter diets 6 % inclusion rate of DDGS are recommended, whereas grow-finish diets could contain 12-15 %[14]. Furthermore, DDGS has been found useful in up to 10-12 % inclusion levels in turkey production[15, 16].

One of the limitations for higher inclusion levels in animal feed diets is mycotoxins. Mycotoxins stem from fungi, and are present in many items produced from crops. It is acceptable in small doses, but during the fermentation process of the bioethanol production, the mycotoxins are concentrated in the distillers grains[17]. Therefore, implementing high inclusion levels can cause contamination of the livestock.

Sulphur is also present in DDGS and can also prove a problem. Corn contains sulphur, and the yeast produces additional sulphites during fermentation. Due to the typical choice of acid, the dry grinding process also tends to produce more sulphuric DDGS than does wet grinding. The sulphur is necessary, but high concentration may prevent the livestock from absorbing other minerals[18]. DDGS also tends to have high levels of phosphorus. It is required in the livestock diet, but high amounts in the manure can be problematic[10].

As mentioned above, the level of inclusion of DDGS in feed composites for different livestock vary, but as DDGS quality improves, these inclusion levels seem to be rising[19].

In table 1, estimates of how much one ton of DDGS can reduce the amount of soy bean meal and cereal in feed rations is shown. As it can be seen it varies depending on the type of DDGS and the surveys conducted. In some surveys, one tonne of DDGS can substitute more than one tonne of soy bean meal and cereal combined.

Table 1. Reductions in soya meal and cereal content of animal feed

	One ton Co-product	Substitution for		
		Soy bean meal	Cereal	Total
		-----------------------tonnes ---------------------		
CE Delft (2008)	Wheat DDGS	0.50	0.66	1.16
	Maize DDGS	0.45	0.69	1.14
Lywood et al (2009)	Wheat DDGS	0.59	0.39	0.98
	Maize DDGS	0.40	0.49	0.89

Source: Lywood (2010)[20], Delft (2008)[21] , Lywood et al (2009)[22].

There is some discussion as to how high the potential for using DDGS to replace soy bean meal is, but it is widely believed that with improvements in uniformity and recognised standards, DDGS may replace more soy bean meal. Some of the possibilities for improving the use of DDGS in livestock diets are to add synthetic essential amino acids (EEAs) or to increase the digestibility.

2.2 Do farmers acknowledge DDGS as a suitable animal feed

General acceptance of DDGS among farmers worldwide still faces some barriers. First and foremost, a standard stipulating the nutritional contents of DDGS would be highly beneficial in creating a deeper market worldwide for the product. Buyers and particularly farmers need to have a degree of certainty of the contents of the product. One reason for the current favourable prices of DDGS relative to traditional feed sources could be that farmers still have uncertainty concerning the product.

One of the points of criticism raised against the extended use of DDGS is that no particularly specific requirements as to the quality of DDGS exists[19]. This is reflected in the different surveys, where the area of origin of the applied DDGS is stated because the nutritional value and contents of the applied DDGS depend upon the specific process of producing DDGS at the location. Many of the studies, who reported enhanced performance, also noted that the DDGS used in the study was of high quality. Differences in quality may be one of the main reasons for the variations in the studies of the effects of DDGS. The different levels of yet unranked quality together with lack of transparency in nutritional values also make pricing in the market for DDGS more problematic and decreases market efficiency.

Implementing standards for DDGS seems to be an important step forward in making the market more accessible to newcomers and provide a guideline to the academic research being performed within the area. This may result in more conclusive results and broader agreement as to the actual advantages and drawbacks of using DDGS in livestock diets.

Thus, there is a need to establish criteria and uniformity of DDGS-products. This is not unique to DDGS but has often been the case of agricultural products. At the international level, the Codex Alimentarius of the UN and the Sanitary and Phytosanitary Standards Agreement of the WTO provide a set of requirements that agricultural products have to fulfil in order to be internationally tradable. Increasingly, however, standards are being set by large corporations and exchanges such as the Chicago Mercantile Exchange or agreed upon between leading companies in the market. This is likely to happen to DDGS over time as well, however, since DDGS is still a relatively recent product, technology and production process development is still taking place at a rapid pace, which leads to products with differing qualities and properties among bioethanol plants. Nevertheless, when the technology and production process matures combined with increased production, use and trade of DDGS, a higher degree of uniformity of the end product is likely to occur eventually resulting in de facto standards.

2.3 Possible economic gains of switching to DDGS feeding

The savings in feed costs by using DDGS obviously depends upon prices of DDGS relative to standard feed stuff. Thus, the price of DDGS is expected to be determined relative to prices of standard feed stuff in order to make DDGS profitable for farmers to choose. Otherwise, if DDGS is priced too high and therefore not being chosen by farmers, DDGS have little value in alternative uses.

One study[23] analysing the economic gains of switching to DDGS feeding in an American dairy herd, suggests that including 4 to 9 % DDGS in the food diet is profitable for farmers when DDGS is priced between 380 to 213 US$/ton, with corn costing 260 US$/ton. With these prices net farm profits per cow were estimated to increase by 1 to 5 % depending upon the price of DDGS. Looking at current prices (June 29, 2012) from Chicago Mercantile Exchange for corn as well as the price of DDGS from an ethanol plant in Des Moines, Iowa, corn was priced at 247 US$/ton while DDGS was priced at 231 US$/ton. Given these prices relations in the US market it should be profitable for farmers to include DDGS into American dairy herd’s feed rations, especially when it seems that DDGS is priced below the corn price in the US market, with no additional price for the higher protein content found in DDGS.

Another statistical study[24] analysing the use and economic viability of DDGS as substitute for traditional feed stuffs also confirms that the price of DDGS correlates more with energy-oriented feed, such as corn, than with protein feed such as soy beans.

Putting this into a Danish perspective one could try to calculate a possible price level for DDGS sold on the Danish market, when used as feed in a Danish dairy cow herd. This is done in table 2 where a standard fodder plan from Farmtal online is highlighted in the first four columns of the table.

Table 2. **Fodder budget for a Danish dairy cow with young stock (2012)**

	Farmtal			CE Delft (2008)			Lywood et al (2009)		
Costs, Dkr.		Price			Price			Price	
Wheat DDGS	0 kg		0	-768 kg	**2.22**	-1708	-729 kg	**2.04**	-1490
Soy bean meal	-430 kg	2.48	-1066	-46 kg	2.48	-114	0 kg	2.48	0
Cereals	-507 kg	1.49	-755	0 kg	1.49	0	-223 kg	1,49	-332
Other inputs			-13492			-13492			-13492
Total cost			-15314			-15314			-15314
Production value (milk & livestock)			25441			25441			25441
Margin per cow, Dkr.			10127			10127			10127

Source: Farmtal online accessed July 2012. Videncentret for Landbrug and own calculations.

In the initial Farmtal fodder budget, the total cost of soy bean meal, cereals and other inputs amounts to 15314 Dkr., while the sale of milk and meat in bring 25441 Dkr. resulting in a profit per cow of 10127 Dkr. In the standard fodder plan 430 kg. of soy bean meal and 507 kg. of cereals is fed to the dairy cow herd, but this could be reduced if DDGS was introduced into the fodder plan. Using Delft's and Lywood's substitution rates for wheat DDGS presented in table 1 above, it should be possible to reduce the amount of cereals/soy bean meal by using 768 kg and 729 kg of DDGS respectively in the two alternative fodder plans. If the farmers profit per cow was to remain unchanged at 10127 Dkr. and all other prices remain the same, then the highest possible price for 1 ton of wheat DDGS in Denmark would be roughly 2040 – 2220 Dkr/ton (340 - 360 US$/ton). If the price was higher than 2040 – 2220 Dkr/ton, then profits per cow would decline and farmers would continue to use cereals and soy bean meal in their feed rations.

If the price relations between cereals and DDGS in Denmark were to follow the US market, then 1 ton of DDGS would cost roughly the same as cereal, 1500 Dkr/ton (250 US$/ton). This would raise the dairy farmer's profits per cow by 400 to 550 Dkr corresponding to a 5% increase. The assumed inclusion rate is 10%, which could possibly be raised even further to around 20 - 30 %, which could further increase farmers' profits. Therefore, presuming that the Danish pricing relationship between DDGS and traditional feed follows the US market, including DDGS in the feed ration would produce extra profits for farms. Given that the US exports large amounts of DDGS, it would be expected that the price level in Denmark would be highly influenced by the US export prices of DDGS, if Danish farmers adopts DDGS in their feed rations.

3. Production and trade of grain based by-products

3.1 Global production

Looking at the OECD-FAO Agricultural Outlook for 2011-2020[25], it becomes apparent that the USA, Canada and the EU27 are the major producers of grain-based ethanol and thereby also the by-products associated with this production (incl. DDGS). In the USA, it is mainly maize based ethanol production while in Canada and the EU27 ethanol production is based on both wheat and maize.

In Table 3, it can be seen that it is projected that the EU27 and USA by 2020 are the main grain based bioethanol producers in the world, expanding their use of grains in the production of bioethanol in the period from 2008/10 to 2020. This of course also increases the potential availability of the by-product DDGS in the USA and EU27 in the coming years.

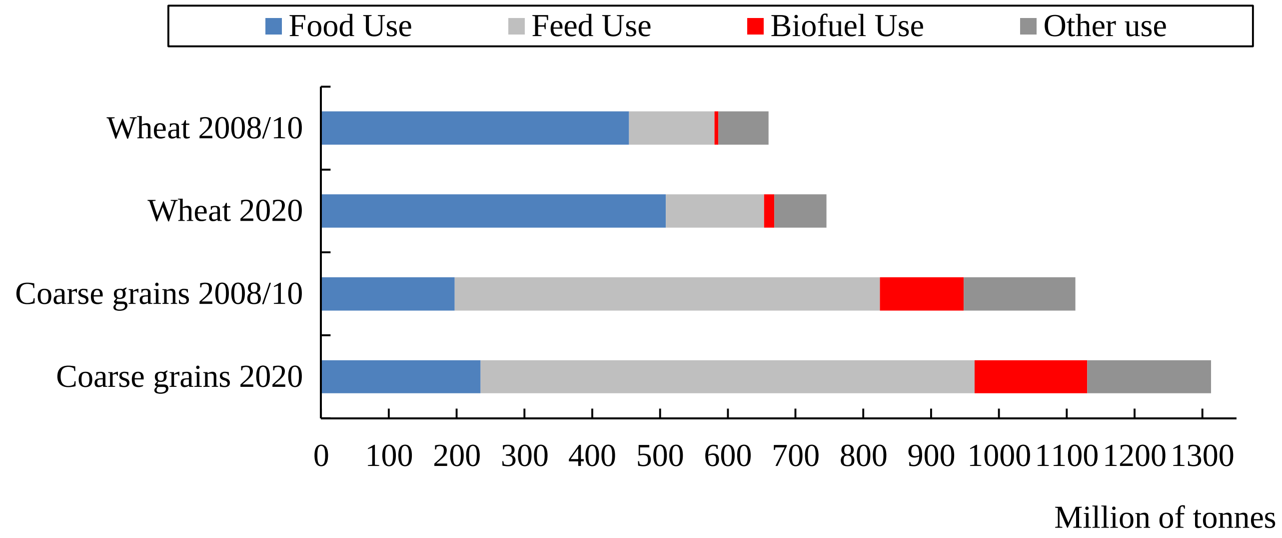
Table 3. The world's use of wheat and coarse grains in bioethanol production, (million tonnes)

	Wheat		Coarse grains	
	2008/10	2020	2008/10	2020
EU27	4	11	4	14
Canada	1	2	3	3
USA	0	0	111	141
China	0	0	4	4
Rest of world	1	1	2	3
Total world	6	15	124	166

Source: OECD-FAO (2011)[25] and own calculations.

Putting this into a global context, figure 3 shows the world consumption of wheat and coarse grains, particularly maize, specified by use. In the case of wheat/coarse grains 6/124 million tonnes are used in the manufacture of bioethanol in 2008/10 increasing to 15/166 million tonnes in the OECD-FAO forecasts for the year 2020. This amounts to respectively 2 and 13 per cent of the world's use of wheat and coarse grains in the year 2020 being used in bioethanol manufacturing. However, a significant share of the use of wheat and coarse grains for bioethanol production is transferred back to feed use through the production of by-products (DDGS).

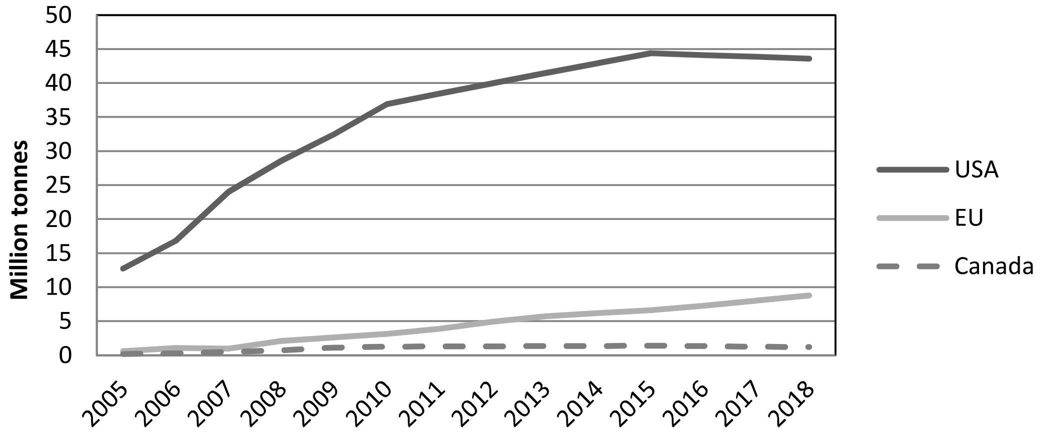
Figure 3. World consumption of wheat and coarse grains including maize



Source: OECD-FAO (2011)[25] and own calculations.

In an earlier Agricultural Outlook for the period 2009 – 2018[26], OECD-FAO estimated the amount of DDGS being produced in USA, Canada and the EU. Figure 4 below illustrates the substantially increasing availability of DDGS in recent years with USA being the largest supplier. Production is expected to rise substantially in coming years. In 2018, the US is projected to produce 44 million tonnes compared to the EU’s 9 million and Canada’s 1 million tonnes. Using the estimates of bioethanol production from table 3, China and the rest of the world have potential for producing around 2.5 million tonnes of DDGS, which would amount to a global production of roughly 57 million tonnes of DDGS in the year 2018

Figure 4. Production of DDGS by major producers of wheat and coarse grain-based ethanol



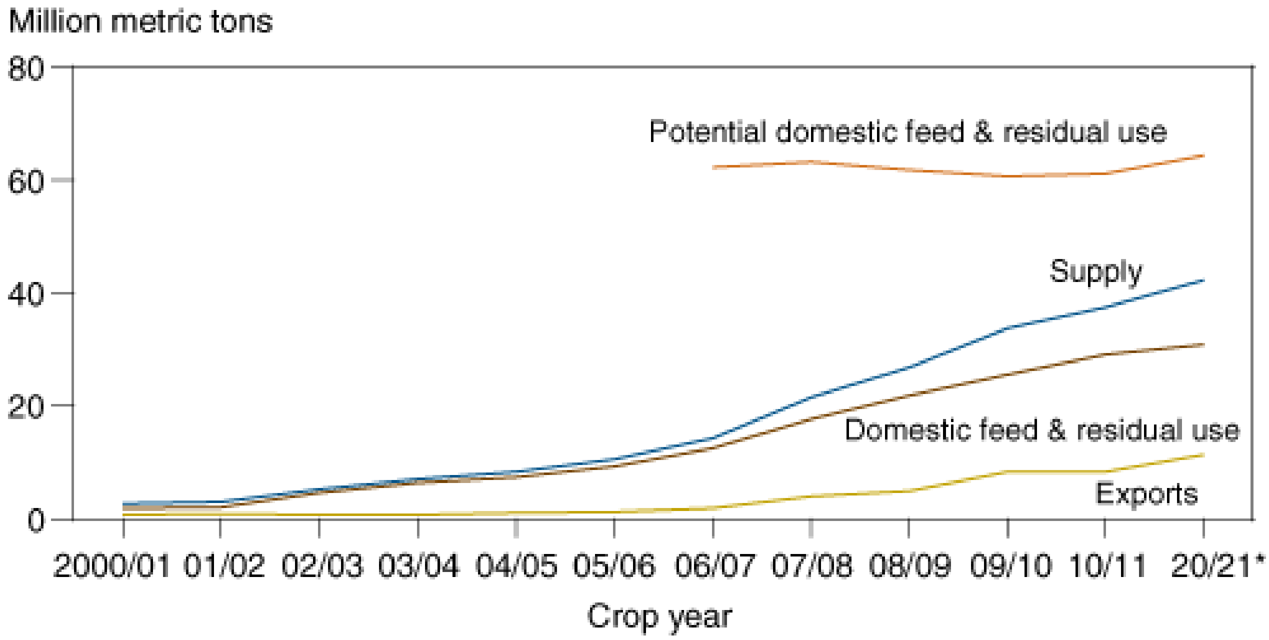
Source: OECD-FAO (2009)[26].

The projections are, naturally, based on assumptions concerning the future profitability of grain-based ethanol production, which to a large extent depends upon the oil price. Nevertheless, the OECD-FAO projections suggest that increasing amounts of DDGS will be marketed in the coming decade.

Looking at the USDA's own estimates for the year 2010/11 the potential demand for bioethanol by-products in the form of DDGS is roughly 61 million metric tonnes on the US market but only about 38 million tonnes is available as animal feed, with 9 million tonnes being exported and 29 million tonnes being fed to animals in the US, figure 5.

Applying the same assumptions as used by the USDA in figure 5, the potential global demand for DDGS could be as much as 700 billion tonnes, when only taking the number of cattle in the world into consideration. Thus, bioethanol producers are not limited by future potential demand for DDGS provided the price and quality is competitive.

Figure 5. Potential feed use and supply of DDGS in the US



*: Projected

Source: Hoffman and Baker (2011)[27], Hoffman and Baker (2010)[28], Hoffman and Baker (2011)[29].

3.2 World trade

Global exports of brewing/distilling dregs and waste, where DDGS exports are registered together with other by-products from beer/alcohol brewing, is recorded in the United Nations COMtrade database. The database clearly shows that the USA is the largest exporter, see table 4. Nearly 100 % of US exports in the COMtrades classification of dregs and waste consists of DDGS, the USDA informs. The USA accounts for 90 per cent of the value of exports within this category in the year 2010 followed by the EU27 with 7 per cent.

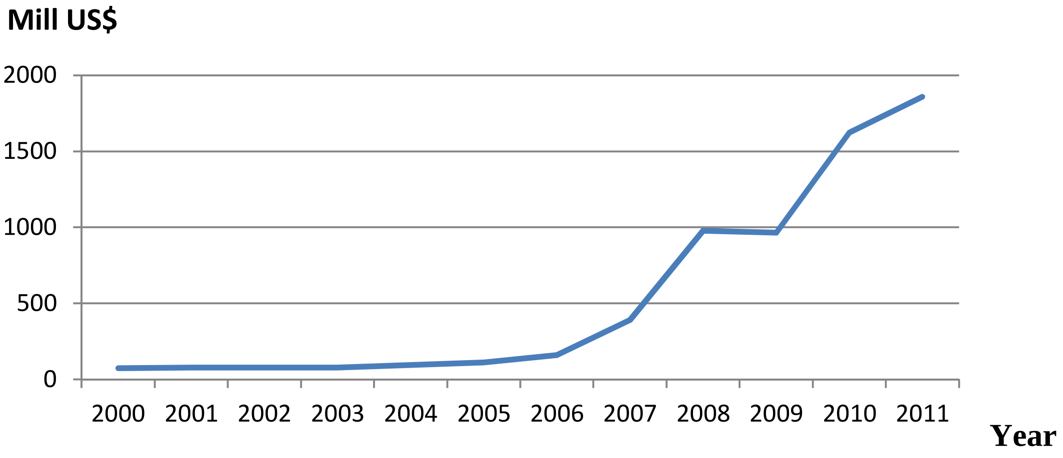
Table 4. Exports of Brewing/distilling dregs & waste including DDGS, 2010

	Million US$	Share	Million Tonnes	Share
Canada	54	3	0.5	5
EU27	122	7	1.1	10
USA	1623	90	9.0	84
Rest of World	13	1	0.1	1
Total world	1812	100	10.7	100

Source: United Nations Commodity Trade Statistics Database, Comtrade.

The value of USA dregs and waste exports has been increasing substantially over the years, from roughly 75 million US$ a year in the period 2000 – 2005 to 1859 million US$ in 2011.

Figure 6. Value of Brewing/distilling dregs and waste exports, mainly DDGS, from the USA



Source: United Nations COMtrade and Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics

Figure 6 shows that the higher production of bioethanol has increased the US exports of dregs and waste, which can be attributed to the bioethanol by-production of DDGS. The minor export in the beginning of the period may most likely be contributed to the remnants of the beer brewing process, which is also used as animal feed.

The main countries importing DDGS from the USA are Mexico, China, Canada and Vietnam accounting for roughly 60 per cent of US exports. DDGS provide a cost-effective alternative to other feed types leading to the exports shown in table 5.

In the case of China, imports of DDGS have dropped significantly from 2010 to 2011. Generally, the need for imports of feed is a function of domestic production of feed crops as well as changes in prices for competing feed crops. Chinas imports are, furthermore, politically regulated and monitored and are thus subject to discretionary changes in trade volumes. Nevertheless, developing countries import close to 4/5 of US exports (78%).

Table 5. **USA exports of mainly DDGS, 2010/2011**

	2010		2011	
	Million Us$	Million tonnes	Million Us$	Million tonnes
Mexico	284	1.7	444	1.8
China	504	2.5	340	1.4
Canada	152	1.0	159	0.7
Vietnam	81	0.4	126	0.5
Korea, South	102	0.5	76	0.3
EU27	78	0.4	76	0.3
Japan	38	0.2	71	0.3
Indonesia	48	0.3	62	0.2
Taiwan	25	0.1	60	0.2
Israel	28	0.2	54	0.2
Thailand	54	0.3	50	0.2
Morocco	23	0.1	42	0.2
Rest of world	210	1.2	298	1.3
Total	1627	9.0	1859	7.6

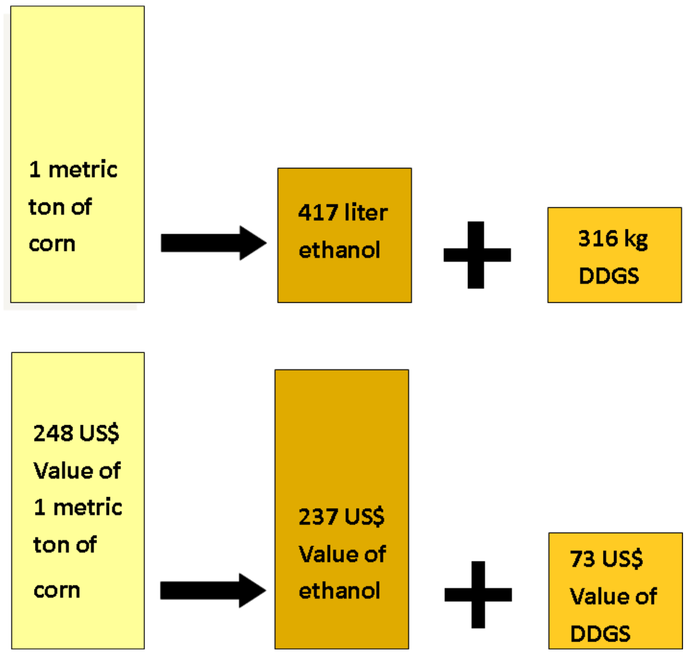
Source: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics

3.3 DDGS's contribution to making ethanol plants profitable

Figure 7 below illustrates the importance of DDGS sales revenue for an Iowa ethanol plant in 2012. As can be seen the plant produces 417 litres of ethanol and 316 kg of DDGS from one metric ton of corn. Based on current prices, 24 % of the value generated by the ethanol plant is derived from DDGS.

The combined sales value of ethanol and DDGS amounts to 25 % more than the value of the corn used, but additional production costs in the form of labour, energy use, capital costs, etc. are also incurred, which are not taken into account in figure 7. Nevertheless, the figure shows that DDGS comprises a significant part of the sales revenue generated by the ethanol plant, around 25 %, without which the production value of the plant would fall below costs.

Figure 7. Production and value of ethanol and DDGS from corn



Source: USDA Market News Service, Des Moines, IA Jodee Inman 515-284-4460 24 Hour recorded market information 515-284-4830.

4. Biofuel production and land use.

Increasing bioethanol production raises the demand for maize/wheat crop land but the substitution of DDGS for wheat and coarse grains in livestock feed mitigates the requirement for additional land and is thus an important part of the equation. When changing the utilisation of the land from one crop to another or from forestry to cultivation, this induces alterations in both greenhouse gas (GHG) emissions and the required amount of land. Although bioethanol replaces fossil fuels, the positive effects of converting to bioethanol compared to gasoline concerning GHG emissions have been suggested to be outweighed from turning forests and grasslands into grown land[30]. Therefore estimates of net land conversion rates for each gross hectare of grain production diverted to fuel use, taking into account feed by-products, is an important issue.

In order to estimate the effects of land use changes, caused by bio-ethanol production, it is necessary to use a comprehensive model to capture the “direct” land use change effects of by-products reducing feed crops production and the “indirect” land use change effects of changed demand and thereby prices for land. Quite a few studies using different models analyses the land use effects, however, often the focus is on greenhouse gas emissions. Furthermore, by-products of bioethanol production have only recently been given serious attention. A European Commission report[31] compares models and results for biofuels production from different feed stocks. The results show quite a large range of global land use change with models estimating a use of around 0.2 to 0.8 hectares of land per ton of oil equivalent produced. Naturally, these estimates are caused by different kind of models being used, where different assumptions are applied.

In Table 6, five studies of land use change due to the use of grains in bioethanol production are highlighted.

The first study by Lywood et al[22] suggests that the effect of DDGS reduces the amount of land required for bio-ethanol production by 94 % directly. Thus 1.0 hectare of wheat processed through a bioethanol plant would produce enough by-products/feed so that the grown area with feed can be reduced by 0.94 hectares. If all other agricultural land use in the world remains unchanged (except land used for bioethanol and feed crops) then the total agricultural areas in the world would have to increase by 0.06 hectare for every hectare of grains grown for biofuel production. The study's assessment is based on yields in North Western Europe.

Table 6. Estimates of land use change, Hectares

	Biofuel crop.	Land use change: Reduced land requirement for feed crops	Land use change: New land required for bio fuel crops
Lywood et al (2009)[22]	1.0	0.94	0.06
Darlington (2009)[32]	1.0	0.71	0.29
Weightman et al (2011)[33]	1.0	0.40	0.60
Fabiosa (2009)[34]	1.0	0.37 to 0.60	0.63 to 0.40
Hertel et al (2010)[35]	1.0	0.31 + 0.41*	0.28

Note * The study by Hertel et al includes both direct land use changes of reduced requirement for feed crop land due to DDGS (0.31) but also includes indirect land use changes due to increased demand for bio fuel crop land, raising land prices and thereby increasing food and non-food prices. These increased food and non-food prices reduce global demand for these products which again reduce the amount of land required for production. (0.41).

The Darlington study[32] suggests that the effect of DDGS reduces the amount of land required for bio-ethanol production by nearly 71 % directly in the US. This assessment is based on increasing yields and estimating that 1 kg of DDGS replaces 1.28 kg of base feed. The study estimates that the reallocation of crops within the US will meet the need of increased bioethanol production without expanding the agricultural area in the US. Moreover, the amount of cotton grown in the US is expected to decline as cotton production expands in China and India. At the same time it is assumed that the corn, wheat and soy bean exports to the rest of the world from the US would remain nearly unchanged due to primarily yield increases.

Weightman et al[33] estimates the net land area required and ethanol output from 1 hectare of land in Europe, growing variable proportions of wheat and sugar beet. In his calculation where 94 % of the bio mass stems from wheat and 6 % from sugar beet he estimates that DDGS reduces the amount of land required for bio-ethanol production by 40 %. But Weightman's estimates are based on a combination of prior studies referring primarily to Lywood (2009) and updated crop yield averages for the EU27.

Fabiosa[34] estimates based on US data, that the direct effect of using DDGS reduces land use between 37 % and 60 %. The wide range in the estimates is due to different modelling assumptions, in particular feed diet compositions and varying yields of different crop types of land replaced.

Finally Hertel et al[35] estimates the direct effect globally of biofuel's by-products/feed production to reduce the required feed crop area by 0.31 hectares for every hectare of biofuels grains grown. This is in the lower range of the presented estimates compared to the other studies presented in table 6. In Hertel's study, DDGS only reduces the amount of corn in livestock corn-based feed with no substitution of soy bean meal. This explains to some degree the low estimate (0.31 hectares) since the substitution of soy bean meal in animal feed would lead to a larger reduction in feed area than only reducing corn-based feed.

Nevertheless, Hertel's study goes one step further than the other studies presented in table 6 by also estimating the indirect land use changes caused by an increase in corn based bioethanol production in the US. The comprehensive model used in the study also highlights the fact that increased demand for land due to higher bioethanol production would raise the price of land; pushing up prices for food and non-food products grown on land. This would lead to an intensification of production (use of more inputs per hectare to increase output) reducing the amount of land required to produce a given amount of output. Furthermore, increasing food and non-food prices would reduce the global demand for these products and reduce the amount of land needed. These indirect effects of land price changes are estimated to reduce demand for land by 0.41 hectares, which added together with the reduction of 0.31 hectares due to DDGS feed, results in a net land conversion of just 0.28 hectares for each gross hectare of corn production diverted to bioethanol production.

This comprehensive estimate has been highlighted in a report from the EU-Commission[31] published in 2010 as the most realistic estimate of global land use change due to an expansion of US bioethanol production. This report specifically considers indirect land use change from increased biofuels demand using a comparison of models and results for marginal biofuels production from different feedstock.

These indirect land use changes are not taken into account in the first three studies presented in table 6. But in Lywood's study for example the indirect effect would by minor since only 0.06

hectares of new land is required for every hectare diverted to fuel use. Darlington's study predicts no change in the agricultural area in the USA but a change in cropping patterns within the country together with increased yields per hectare. Given his assumption of nearly unchanged quantities of exports from the US one could argue that future increased yields in the US are not going to contribute to feed the increasing world population directly, but the expansion of DDGS exports would alleviate the situation. Particularly, in the foreseeable future, where meat consumption is expected to increase rapidly around the globe due to population and income increases, demand for protein feeds increase proportionally. Thus, the market for animal feed presents an opportunity for alternatives like distillers grains and mitigates to some extent the use of land resources in the production of bioethanol.

Summing up, the studies on land use effects of bioethanol production show albeit with variations that the land required for bioethanol production is substantially reduced by the feed effect of the by-product DGS. The impact estimates of bioethanol production on other parts of the economy depend, however, upon the assumptions and models applied. When 1 hectare used in bioethanol production result in by-products corresponding to an area of less than 1 hectare of feed crops, a comprehensive model estimating the effects of land price changes is needed. The lower the direct feed effect is the higher is the impact upon the rest of the economy including land and food prices.

References

1. Ferrett, G. (2007): *Biofuels ‘crime against humanity’*. BBC Online.
2. Bremer, V.R., A.K. Watson, A.J. Liska, G.E. Erickson, K.G. Cassman, K.J. Hanford and T.J. Klopfenstein (2011): *Effect of distillers grains moisture and inclusion level in livestock diets on greenhouse gas emissions in the corn-ethanol livestock life cycle*, The Professional Animal Scientist, vol. 27, pp. 449-455.
3. Schingoethe, D.J. (2007): *Strategies, benefits, and challenges of feeding ethanol by-products to dairy and beef cattle*, Proc. 18th Florida Ruminant Nutrition Symposium, Gainesville, Florida, USA.
4. Mathews, Jr, K.H. and M.J. McConnell (2009): Ethanol co-products use in U.S. cattle feeding, USDA-ERS, Outlook No. (FDS-09D-01).
5. Schingoethe, D.J. (2006). *Utilization of DDGS by cattle*. Proc. 27th Western Nutrition Conf. Winnipeg, Manitoba, Canada, pp. 61-74.
6. Hoffman, L.A. and A. Baker (2011): *Estimating the Substitution of Distillers’ Grains for Corn and Soybean Meal in the U.S. Feed Complex*, Report, USDA-ERS.
7. Corrigan, M.E., G.E. Erickson, T.J. Klopfenstein, M.K. Luebbe, K.J. Vander Pol, N.F. Meyer, C.D. Buckner, S.J. Vanness and K.J. Hanford (2009): *Effect of corn processing method and corn wet distillers grains plus solubles inclusion level in finishing steers*, Journal of Animal Science, vol. 87, pp. 3351-3362.
8. U.S. Grains Council (2007): *DDGS User Handbook.*
9. Chen, Y.-K. (2004): *Evaluation of Distiller’s Dried Grains with Solubles for Lactating Cows in Taiwan*, AGAPE Dairy Consultant.
10. Schingoethe, D.J., K.F. Kalscheur, and A.D. Garcia (2002): *Distillers Grains for Dairy Cattle*, SDSU Extension Extra. ExEx 4022.
11. Stein, H.H. (2008): *Use of Distillers Co-products in Diets Fed to Swine*, in “Using Distillers Grains in the U.S. and International Livestock and Poultry Industries,” Midwest Agribusiness Trade Research and Information Center at the Center for Agricultural and Rural Development, Iowa State University, pp. 79-97.

12. Wilson, J.A., M.H. Whitney, G.C. Shurson, and S.K. Baidoo (2003): *Effects of Feeding Distillers Dried Grains with Solubles (DDGS) to Gestation and Lactation Diets on Reproductive Performance and Nutrient Balance in Sows*, Journal of Animal Science, vol. 81.
13. Bregendahl, K. (2008): *Use of Distillers Co-products in Diets Fed to Poultry*, in Using Distillers Grains in the U.S. and International Livestock and Poultry Industries, Midwest Agribusiness Trade Research and Information Center at the Center for Agricultural and Rural Development, Iowa State University, pp. 99-133.
14. Lumpkins, B.S., A.B. Batal, and N.M. Dale (2004): *Evaluation of Distillers Dried Grains with Solubles as a Feed Ingredient for Broilers*, Poultry Science, vol. 83: pp. 1891-96.
15. Noll, S.L., J. Brannon, and V. Stangeland (2004: *Market Turkey Performance and Inclusion Level of Corn Distillers Dried Grains with Solubles*, Poultry Science vol. 82.
16. Roberson, K.D (2003): *Use of Dried Distillers' Grains with Solubles in Growing-finishing Diets of Turkey Hens*, International Journal of Poultry Science vol. 2, pp. 389-93.
17. Wu, F. and G.P. Munkvold (2008): *Mycotoxins in Ethanol Co-products: Modeling Economic Impacts on the Livestock Industry and Management Strategies*, Journal of Agricultural and Food Chemisry, vol. 56. pp 3900–3911.
18. Snider, T.A. (2004): *Distillers Grains and Sulfur White Paper*, National Corn Growers Association.
19. Weightman, R.M., B.R. Cottrill, J.J.J. Wiltshire, D.R. Kindred and R. Sylvester-Bradley (2011): *Opportunities for avoidance of land-use change through substitution of soya bean meal and cereals in European livestock diets with bioethanol coproducts*, GCB Bioenergy, vol. 3, pp. 158-170.
20. Lywood, W. (2010): *Issues of concern with models for calculating GHG emissions from indirect land use change*, report, Ensus.
21. Delft, C.E. (2008): *Estimating indirect land use impacts from by-products utilization* , study commissioned by AEA Technology as part of the Gallagher Biofuels Review for Renewable Fuels Agency Department for Transport.
22. Lywood, W., J. Pinkney and S. Cockerill (2009): *Impact of protein concentrate coproducts on net land requirement for European biofuel production*, Journal of GCB Bioenergy, vol. 1, pp. 346-359.

23. Schmit, T.M., R.N. Boisvert, D. Enahoro, and L.E., Chase. (2009): *Optimal dairy farm adjustment to increased utilization of corn distillers dried grains with solubles.* Journal of Dairy Science (2009): 6105-6115.

24. Beckman, J., R. Keeney and W. Tyner (2011): *Feed demands and coproduct substitution in the biofuel era*, Agribusiness, vol. 27, pp. 1-18.

25. OECD-FAO (2011): *OECD-FAO Agricultural Outlook 2011-2020*, OECD Publishing.

26. OECD-FAO (2009): *OECD-FAO Agricultural Outlook 2009-2018*, OECD Publishing.

27. Hoffman, L.A. and A. Baker (2011): *Market Potential for U.S. Distillers' Grains Exceeds Likely Supply Growth*, Report, USDA-ERS.

28. Hoffman, L.A. and A. Baker (2010): *Market Issues and Prospects for U.S. Distillers' Grains Supply, Use, and Price Relationships*, Report, USDA-ERS.

29. Hoffman, L.A. and A. Baker (2011): *Estimating the Substitution of Distillers' Grains for Corn and Soybean Meal in the U.S. Feed Complex*, Report, USDA-ERS.

30. Schingoethe, D. (2008): *Use of distillers co-products in diets fed to dairy cattle*, in B.B. Babcock et al. (ed.) Using distillers grains in the U.S. and international livestock and poultry industries, MATRIC Iowa State Univ. Ames, pp. 57–78.

31. Edwards, R., D. Mulligan and L. Marelli (2010): *Indirect Land Use Change from increased biofuels demand - Comparison of models and results for marginal biofuels production from different feedstocks*, Report, European Commission, Joint Research Centre, Institute for Energy.

32. Darlington, T.L. (2009): *Land Use Effects of U.S. Corn-Based Ethanol*, Air Improvement Resource, Inc.

33. Weightman, R.M., B.R. Cottrill, J.J.J. Wiltshire, D.R. Kindred and R. Sylvester-Bradley (2011): *Opportunities for avoidance of land-use change through substitution of soya bean meal and cereals in European livestock diets with bioethanol coproducts*, GCN Bioenergy, vol. 3, pp. 158-170.

34. Fabiosa, J.F. (2009): *Land-Use Credits to Corn Ethanol: Accounting for Distillers Dried Grains with Solubles as a Feed Substitute in Swine Rations*, Center for Agricultural and Rural Development, Iowa State University, Working Paper 09-WP 489.

35. Hertel, T.W., A.A. Golub, A.D. Jones, M. O'Hare, R.J. Plevin and D.M. Kammen (2010): *Effects of US maize ethanol on global land use and greenhouse gas emissions: Estimating market-mediated responses*, Bioscience, vol 60, pp. 231.