DISTILLERS GRAINS AND THE LIVESTOCK INDUSTRY

IN

WESTERN CANADA

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Abstract

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Distillers Grains and the Livestock Industry in Western Canada.

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The ethanol industry in Western Canada has seen significant growth in recent times spurred on mainly be environmental considerations. For a region with substantial grain production, increased prices from additional demand by the biofuel industry may inure to the benefit of grain farmers and land owners in the long term. The livestock industry however remains in a complex position facing the possibility of higher feed costs on the one hand and potential savings in feed cost on the other, with the availability of distillers grains- a by-product from ethanol production. The sectorial implications for the livestock sector could also be diverse and dependent upon the capacity to incorporate the distillers grains into the different feed rations. There is also the possibility of a spill-over effect from the US distillers grains market. This study therefore sought to complement current nutritional research by providing an economic perspective of the impact of distillers grains on the livestock industry in Western Canada.

Focussing primarily on the beef cattle and hog industries, the study applied both linear programming and time-series techniques to assess potential benefits and costs. Potential positive economic benefits were observed for the inclusion of wheat and corn distillers grains with the former having a higher economic value in the high-protein feed segments.

Dependent on market factors such as the price of substitute feeds, exchange rates and transportation considerations, the magnitude of these savings could range between $7.29 and $0.34/tonne. The study recommends an understanding of these dynamics in order for livestock

and ethanol producers to derive mutual benefits from the fledging biofuel industry in the Western plains.

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Chapter 1

Introduction

1.0 Introduction

The global biofuels industry has experienced widespread growth in recent years with production tripling from 18 billion litres in 2000 to about 60 billion in 2007 (Coyle 2007). Commencing in Brazil and the US in the mid 1970s and 80s, the large-scale production and expansion of biofuels has seen renewed public sector interest and support. The achievement of broad societal goals i.e., to diversify energy sources, enhance energy security, and meet environmental and rural development objectives are often cited as justifications for governmental support for the industry (Miranowski 2008; Coyle 2007).

Although significantly smaller than the United States (US), the biofuel industry in Canada is not exempted from the recent enthusiasm for renewable fuel production. The industry is made-up of 17 plants with a total operating capacity of about 1.45 billion litres per year (Ethanol Producer Magazine 2009). Environmental considerations aimed at meeting commitments under the Kyoto protocol are often cited as the primary reasons for Canada's ethanol expansion program (Auld 2008).

Ethanol production in North America is led by the US with almost 44 billion litres per year production capacity, 183 operating plants and 20 plants under construction (Ethanol Producer

Magazine 2009). The proportion of US corn used to produce ethanol is expected to rise from 12% to 23% by 2015 (Runge and Senauer 2007).

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The Canadian ethanol industry not unlike expansion models in other leading ethanol producing countries is highly dependent on a myriad of provincial and federal legislation and support. The objective is to obtain an ethanol blend ratio in motor vehicles of 5% nationally by 2010 (Government of Canada 2006). Support measures at the provincial level are made up of an array of fuel tax exemptions, content mandates and producer credits. Provincial policies are mainly driven by the specificities of their respective economies.

The production of ethanol is expected to be consistent with the increasing trends observed since 2002. This may be primarily due to the need to meet mandated levels by 2010. Production in Canada rose from 175 million litres in 2002 to 231 million litres in 2005 and 395 million litres in 2007 (Olfert and Weseen, 2007). Current estimated production capacity is in the region of 1.45 billion litres and is projected to reach 2 billion litres by 2010 (Ethanol Producer Magazine 2009). Laan et al., (2009) projects the expected production capacity for 2012 to be in the region of 2.3 billion litres per year. Figure 1.1 shows the trend in production of ethanol in Canada.

The increasing trend (Figure 1.1) in ethanol production is a result of Provincial and Federal government support instruments implemented to stimulate the growth of the industry. This trend is expected to continue at least until mandated levels are met. Further growth will depend on ethanol demand and export opportunities (McKinnon 2008).

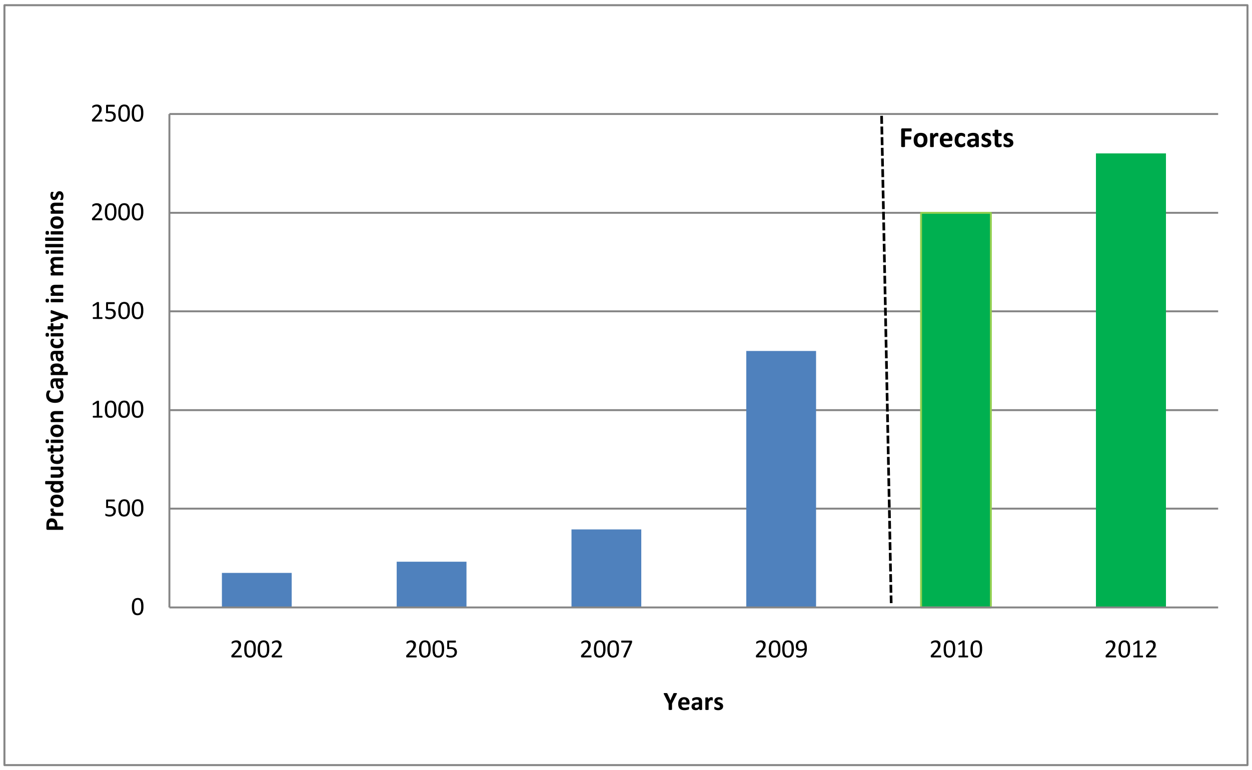


Figure 1.1 Canadian Ethanol Production Outlook

Sources: Olfert and Weesen (2007); Laan et al. (2009).

Canada produces about two-thirds of its ethanol from corn and the rest from wheat. In 2006, total ethanol production utilized an estimated 500,000 tonnes of wheat and slightly more than 1 million tonnes of corn (Agriculture and Agri-Food Canada 2006). Cellulosic ethanol represents only about 0.2% of total production (Auld 2008). Geographically, Canadian wheat based ethanol production is predominant in the west and corn based production is mostly in Central Canada.

Western Canada is home to eight (8) out of the seventeen (17) plants in Canada. Thirty-six percent of total national operating capacity is located in Western Canada with Saskatchewan having the highest operating capacity of 342 million litres per year (MMly) (23.7%). Manitoba accounts for 10% (140

MMly) of total national operating capacity whilst Alberta's production of ethanol amounts to 0.3% (40 MMly). Out of the four Western Canadian provinces, British Columbia is the only province without an ethanol plant. The dependence on wheat as the main feedstock however creates synergies between the industry and agriculture. The agricultural profile of the western plains serves both as an advantage and a potential competitor to the expansion of ethanol production.

1.1 Overview of Agriculture in Western Canada

Western Canada comprises the provinces of Manitoba, Saskatchewan, Alberta and British Columbia. The economy of this region could be described as resource driven. Although differences exist among the Western Provinces in terms of structure, one key similarity is the heavy dependence on natural resources which include agriculture, forestry, oil and gas (Western Economic Diversification Canada 2009). According to Belle (2006), Western Canada has 86% of farm land in Canada out of which the Prairies account for 81.1%. In addition, 58% of farms in Canada are located in Western Canada with Saskatchewan having the biggest share of 21.6% (Statistic Canada 2007).

In Saskatchewan, agriculture, forestry, fishing and hunting together make up 9.5% of GDP (Statistic Canada 2008). Further, in 2008, approximately 58% (i.e. CN$ 26,757,815,000) of total farm cash receipts (i.e. CN$ 45,946,150,000) in Canada was received by farmers in Western Canada (Statistics Canada 2009a). Alberta's farm cash receipts in 2008 totalled about $10 billion, which represented 21.7% of the value of Canada's total agricultural production (Statistics Canada 2009a).

The main contributors to producer incomes are the grains and red meat. In 2007, these two sectors together with oilseeds accounted for the largest share of farm market receipts in the Prairies, whereas in British Columbia higher contributions came from fruits, vegetables and other farm products (Agriculture and Agrifood Canada 2008). Generally, the abundance of land and availability of feed grains can be said to have primarily maintained the viability of the industry although different provinces in the region have different economic advantages. For example, whilst Saskatchewan's relative abundance of land ensures its competitive advantage in the backgrounding of cattle, it tends to lag behind Alberta in terms of slaughter capacity as a result of limited logistics, market structure and economies of scale (Informa Economics 2009). Approximately 77% of the total national head of cattle and calves, i.e. 16,000,000 head, is found in Western Canada (as of July 2006); Alberta accounted for more than 54%, i.e. 6,300,000 head, Saskatchewan, 3,450,000 head with Manitoba having 1,680,000 head (Government of Alberta 2009). Appendix A presents livestock numbers on farms in Western Canada.

1.2 Trends in Feed Grains Supply in Western Canada

Western Canada is noted as a significant producer of wheat, barley and canola. Corn is produced on a comparatively smaller scale mainly in the Red River Valley of Manitoba. In general, few crops have been developed strictly for the production of livestock feeds[1]. Zijlstra and Beltranena (2007) however, noted that a large portion of the crops produced in Western Canada end up in the livestock feeds market. These are usually crops not selected for premium price[2]. For example, barley that is not selected for malting is generally used as feedstock in addition to varieties seeded specifically for

[1] Crops such as field peas are key ingredients in livestock diets particularly hog diets.
[2] The food market is the higher value market

livestock feed (Agriculture and Agrifood Canada 2007). The feed market therefore tends to be the lowest priced market for crops (Zijlstra and Beltranena 2007). Aside from the domestically grown feed grains, the import market especially US corn has become a significant segment of the Western Canadian feed supply.

According to Charlebois and Wensley (2003), corn imports from the United States have become a safety valve for the feed grain market in Western Canada. If Canadian feed grain stocks are tight and prices are high, US corn stocks may end up in Canada (Anderson 2000). Factors such as the substantial increase in livestock production, rises in malting barley exports, low commodity prices and adverse climatic conditions are listed as having contributed significantly to the rapid reduction of the feed grain surplus in Western Canada (Charlebois and Wensley 2003). Figure 1.2 shows the trends in the production of some grains in Western Canada.

A significant feature of the trends in the production of these crops is the similarity in terms of fluctuations in yields. This is expected given that crops are grown in the same geographical area and are therefore subject to the same climatic conditions. For example, in 2002, a dry growing season and an early fall[3] contributed to low yields, high field abandonment and unharvested acres (Statistics Canada 2002). As a result of this, the production of Western Canadian Spring Wheat dropped to 10 million tonnes from 15.7 million tonnes in 2001 (Statistics Canada 2002). Market factors such as low world stocks, low commodity prices as well as climatic conditions in other parts of the world also

[3] Likely refers to freezing temperatures that set in earlier than normal which stops crop growth and destroy quality.

impacts grain production in Western Canada (Racz 2007). This aside, Western Canada remains a major producer of coarse grains.

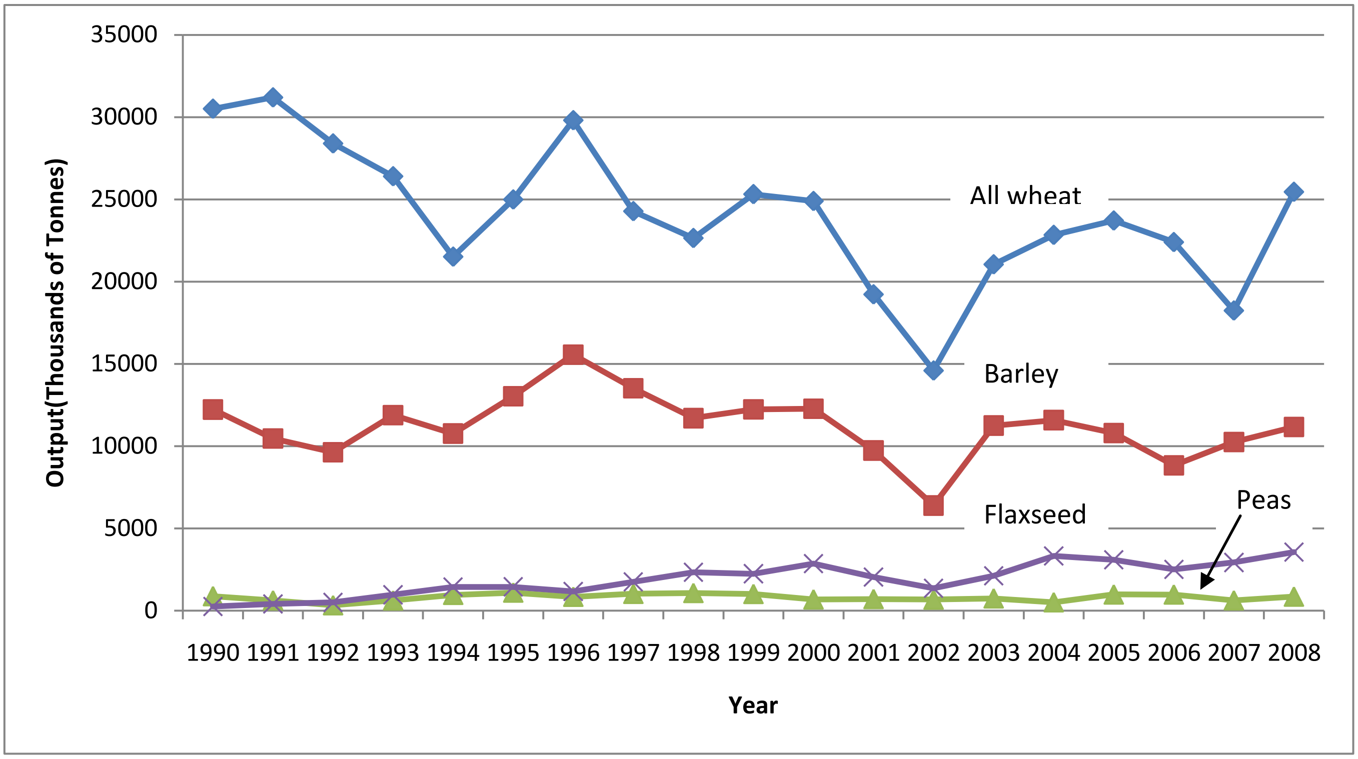


Figure 1.2 Production of Crops in Western Canada

Data source: Canada Grains Council (2009)

1.3 Problem Statement

The production of both grains and livestock represent an important part of the agriculture production of these provinces. Additionally, the Prairies are noted for the production of significant volumes of grains and other field crops such as flaxseed, canola, etc. It is within this context that the recent increase in the development and expansion of ethanol production is situated. Given this organization of the economy of Western Canada particularly the importance of both grain and livestock industries, the expansion of ethanol production could have important consequences.

On the one hand, the expansion in the production of biofuels could increase demand for feed grains, drive up feed grain prices and thereby increase feed costs for livestock producers. Even without significant demand for ethanol, prices of wheat and corn rose by 33% and 34% respectively between 2006 and 2007 whilst livestock prices changed very little (Agriculture and Agrifood Canada 2008). Increased grain prices would be beneficial to grain farmers in the short run and eventually landowners as a result of increased land values. Moreover, higher grain prices could have unequal sectorial implications, especially on the beef cattle and hog industries which are dependent on the market to set prices.

On the other hand, ethanol is produced in conjunction with valuable by-products which can be used in the livestock industry as animal feeds and can substitute for higher priced feed grains in animal rations. Depending on the volumes of distillers grains produced, and the form (i.e. wet or dry) and extent to which they can be incorporated in animal rations, part of the potential increase in livestock feeding costs could be off-set by this by-product. In the best case scenario, feed costs may decrease.

The impact across different livestock sectors may also be quite diverse. For example, dairy and beef species are more adapted to fibrous feed in their feed rations and therefore may be better positioned to gain from increased distillers grains availability in the market. This is in contrast to other livestock producers who may not be able to adjust their feed rations as readily to absorb the increased supply of distillers grains.

Moreover, given the proximity of Western Canada to the US there are two possibilities. Firstly, there is a tendency for ethanol firms in the region to switch to corn depending on relative prices. For example in May 2008, Husky Energy Inc., operators of a 130 million litre ethanol plant in Minnedosa, Manitoba switched to corn from wheat (up to 75% of total feedstock) citing rising wheat costs (Biofuels Digest 2008). As a result, there has been an augmented availability of both pure wheat Distillers Dried Grains with Solubles (DDGS) and wheat/corn blend DDGS (Ortin and Yu 2009). Secondly, there is an additional possibility of the importation and use of corn DDGS in Western Canada by some feedlot operators in Western Canada depending on exchange rates and other cost advantages. In the light of these issues the present study evaluates the impact of distillers grains on the economics of livestock feeding in Western Canada.

The following research questions arise:

1. What is the market potential for DDGS in Western Canada?
2. What are the price relationships between distillers grains and other traditional feeds?
3. What is the economic impact of the corn and wheat DDGS on cattle and hog rations?
4. What is the relative competiveness between wheat and corn DDGS in livestock rations?
5. What is the effect of the prices of other feed substitutes and market factors on the competiveness of distillers grains in livestock rations?

1.4 Relevance of Study

As the ethanol industry rapidly expands in Canada and particularly in the Prairie region, the supply of various distillers co-products are becoming more abundant and available. This phenomenon presents opportunities to reduce feed costs and improve profitability of livestock operations through the utilization of these feeds. However, proper ration formulation, economic analysis and feeding management are important in reaping maximum benefits from the ethanol boom. Most of the research done so far has focused mainly on nutritional considerations. The objective of these studies has often been the nutritional composition of distillers grains and their impact on end product quality of farm animals. The decision to incorporate a given feed ingredient is however an economic decision. Currently, not much has been done on this aspect and the present study attempts to fill this research gap.

The assessment of the impact of distillers grains on the livestock industry seeks to inform policy makers on the linkages and interactions between grain based ethanol production and livestock production in order to provide insightful perspectives on the true cost and benefits accruing to livestock producers. Furthermore, the evaluation of the market potential for the co-product would inform ethanol producers about the size of the market for distillers grains in Western Canada. An understanding of the potential market could ensure that producers market high quality feed products in order to capture market opportunities especially as margins tighten. Ultimately, livestock producers in Western Canada would benefit from the understanding of the economic impact of distillers grains on feed ration cost and livestock production economics in the region.

1.5 Organization of Thesis

The study is organized into six chapters. The first chapter presents an introduction to the study. Chapter two is a review of the relevant literature related to the present study. As a result of the linkages between the Canadian and US markets and recent evidence of the use of corn DDGS in Western Canada, a considerable effort is made to review both corn and wheat based production related literature. A discussion of the theoretical basis for the study is presented in Chapter three. The methodological approach adopted to address the research problem is presented in the subsequent chapter. Chapter five is a discussion of the results of the study. Conclusions and recommendations are captured in the last chapter.

Chapter 2

Literature Review

2.0 Introduction

This chapter presents an outline of literature relevant to the present study. An overview of the production of ethanol is first presented; this is followed by an examination of the role of public policy in ethanol development. A review of literature on the nutritional suitability of the by-product in livestock rations is also presented. The chapter closes with a survey of economic studies on the impact of distillers grains on livestock production.

2.1 Ethanol Production and Refining

Ethanol is a common alcohol produced by the fermentation of organic materials or by the hydration of a petrochemical feedstock (Olar et al., 2000; Auld 2008). Feedstocks used in the production process include corn, wheat, sugar beets and sugar cane. Current research is exploring the commercialization of cellulosic ethanol that uses straw, crop waste, switchgrass, and certain wood products as feedstock.

Ethanol has both industrial (cosmetics, beverages, pharmaceuticals, food extracts) and fuel purposes, with the latter being the focus of the renewed expansion drive. It is the most commonly used biofuel (Miranowski 2008). Its main uses include serving as oxygenate to prevent air pollution from carbon monoxide and ozone; as an octane booster to prevent early ignition and as an extender to gasoline stocks (Yacobucci 2006). Unblended ethanol is usually not used as a motor fuel; instead a percentage of ethanol is combined with unleaded gasoline. Fuel ethanol is typically mixed with gasoline in a 10:90 ratio (E10) or as the primary fuel in an 85:15 ratio (E85) with gasoline (American Coalition for Ethanol 2009).

Ethanol is produced mainly by the process of dry or wet milling. With the former, the entire feedstock is first ground into flour otherwise called meal and processed without separating the various components. After fermentation the resulting 'beer' is transferred into distillation columns where ethanol is separated from the remaining stillage. A centrifuge is used to separate the coarse grain part of the stillage from the soluble. The soluble may be condensed into syrup (Condensed Distillers Solubles) and may be added to the wet coarse component to form Wet Distillers Grain with Solubles (WDGS) or dried together to produce Dried Distillers Grain with Solubles (DDGS) a high quality nutritious livestock feed (Renewable Fuels Association 2009). Carbon dioxide is the other major co-product of the dry milling process.

In the wet milling process, grains are steeped in acids before processing (Klopfenstein et al., 2003). A combination of grinding, differential separation and centrifugation fractionates the kernel. Final products from the wet milling process excluding ethanol may include protein gluten meal, wet feed product, starches and high fructose syrup. Although wet milling produces a greater variety of by-products, the advantage of dry mills is that the plants are significantly less expensive to build whilst having similar operating cost (Coltrain 2004). As such, the dry milling process is dominant. Figure 2.1 illustrates the conventional process of the production of ethanol from grains.

Recent variants in the milling process employ techniques such as corn fractionalization. This technique helps to increase starch availability for ethanol production as well as increase protein concentration of the resulting by-products (Bista et al., 2008).

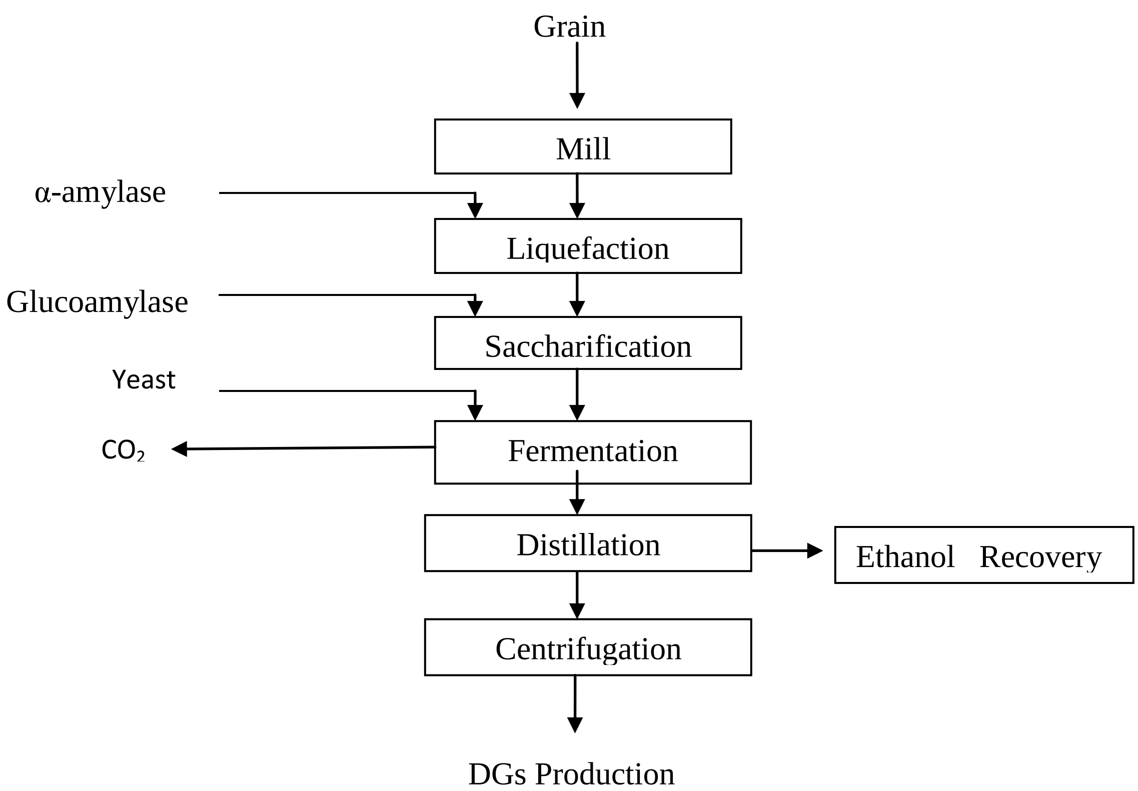


Figure 2.1 Conventional Grain Based Ethanol Production

Source: Mosier and IIeleji (2006)

2.2 Canadian Ethanol Industry

The current Canadian ethanol industry can be described as emerging with the heightened activity spurred on by environmental considerations. Having been in existence at the small-scale level since the late 1970s (Olfert and Weseen 2007), the industry has gone through diverse phases of development reaching its present status today. The first fuel ethanol plant was built in 1980; by 1995 ethanol blended gasoline was sold at over 560 Canadian retail outlets (Johnson 1995).

As of mid 2002; five plants producing fuel ethanol were operating in Canada; one each in Alberta, Saskatchewan and Manitoba and two in Ontario. Total production capacity was about 175 million litres of fuel ethanol per year. The number of retail outlets rose to about 1000 in 2005, with 8 firms in production (Natural Resources Canada 2009). Production estimates in 2007 were in the region of 395 million litres annually, a substantial capacity increase from the 231 million litres produced in 2005 (Olfert and Weseen 2007). Canadian companies are currently producing 1.45 billion litres of ethanol per year, with the expectation of reaching about two billion in 2010 in order to meet mandated levels (Ethanol Producer Magazine 2009). Ontario is Canada's leading ethanol province accounting for approximately 67% of total production capacity. Table 2.1 presents a list of ethanol producing plants in Canada.

2.3 Profitability of Ethanol Production

The continuous production and expansion of ethanol like other economic activities is highly dependent on the profitability of the enterprise. This is important to ensure competitiveness in an industry in which gasoline still remains the dominant fuel. The significant use of federal and state interventions to create incentives (e.g. the use of ethanol subsidies), represents a means to achieving this end (DiPardo 2002). A plethora of factors contribute in different magnitudes to the profitability of ethanol production. The net cost of feedstock relative to price of ethanol (ethanol production margin) and the difference between ethanol and wholesale gasoline prices (the fuel blending margins) are most significant for profitable ethanol production (Yacobucci 2006). Coltrain (2004) estimates that ethanol sales account for 70-80% of revenue, thus making the price of the product a key factor. In addition to price, the marketing of by-products especially distillers grains are significant contributors to profit. According to Bista et al., (2008), the economic viability of ethanol production is heavily dependent on the market value of distillers grains by-product sold as feed to the livestock industry. Estimates of the contribution of the by-product to total revenue are in the region of 10-20% (Coyle 2007; Coltrain 2004).

On the cost side, factors such as the price, type and availability of grains in addition to energy cost make up key operating components. Amongst these, the cost of feedstock is the most dominant cost factor in ethanol production (DiPardo 2002; Eidman 2007). For example, the high input cost of corn prices rising from $2.00 per bushel in the 2005-2006 crop year to $3.95 in the 2007-2008 crop year accounted for the slowdown in the pace of ethanol expansion in the US in 2007 (Collins 2006; Konecny and Jenkins 2008).

Tiffany and Eidman (2003) designed a spreadsheet model to determine the economic returns on a modern 40-million gallon per year plant. According to the authors, corn is the dominant expense and natural gas is the key operating expense. Other cost elements include transportation cost and the cost of chemicals and enzymes. Much as distillers grains remain a key factor in the magnitude of revenue obtained from production, it has the potential to contribute significantly to cost depending on the form in which it is marketed. The contribution of distillers grains to production cost results from increased transportation and energy costs. With the former becoming relevant when distillers grain is marketed wet, whilst the latter is the case when dried.

Konecny and Jenkins (2008) noted that because of high transportation cost, wet distiller's grain is generally fed to cattle within 50 miles of the ethanol plant. According to Erickson (2009), although extra moisture has a positive effect on cattle performance, the increased handling and transportation cost are a significant consideration.

Further, the shelf life of wet distillers grains is related to environmental temperature; is typically stores for 3 to 7 days and requires a sizeable operation to use semi-load quantities before spoilage occurs (Lemenager et al., 2006). Dried distillers grains on the other hand can be stored for extended periods of time and can be shipped greater distances more economically and conveniently, although this comes at an extra cost of drying. According to Coltrain (2004), the additional amount of natural gas required to dry distillers grains to produce DDGS is nearly the same as the amount used to produce ethanol making the decision to sell DDGS or WDGS an important part of the overall profitability for an ethanol facility.

Table 2.1: Ethanol Production in Canada

Company	Location	Primary Feedstock	Province	Capacity(MMly)
Amaizeigly Green LP	Collingwood	Corn	ON	52
Enerkem Inc	Westbury	Woody biomass	QC	1.3
Green Field Ethanol	Chatham	Corn	ON	185
Green Field Ethanol	Johnstown	Corn	ON	200
Green Field Ethanol	Tiverton	Corn	ON	25
Green Field Ethanol	Varennes	Corn	QC	120
Husky Energy	Lloydminster	Wheat	SK	130
Husky Energy	Minnedosa	Wheat	MB	10
Husky Energy	Minnedosa	Wheat	MB	130
IGPC Ethanol Inc	Aylmer	Corn	ON	150
Kawartha Ethanol*	Havelock	Corn	ON	80
NoraAmera Bioenergy Corp.	Weyburn	Wheat	SK	25
North West Bioenergy Ltd	Unity	Wheat	SK	25
Permolex International LP	Red Deer	Wheat	AB	40
Pound-Maker AgVentures Ltd	Lanigan	Wheat	SK	12
St. Clair Ethanol Plant	Sarnia	Corn	ON	200
Terra Grains Fuel	Belle Plain	Wheat	SK	150

Source: Ethanol Producer Magazine (2009) *plant under construction

2.4 Ethanol Production and Government Policy

The preceding section discussed the issue of profitability mainly examining factors within the ambit of the ethanol firms. Aside from these, there are external factors that impact rather significantly on the profitability of the enterprise. One such factor is the price of oil. In general ethanol production becomes competitive when oil prices increase since they can be regarded as substitutes[4]. Given the volatility of the oil market, players in the ethanol industry are subject to a considerable degree of risk and uncertainty. Governments therefore tend to provide assistance to help fledgling biofuel enterprises overcome cost and scale disadvantages and minimize inherent fluctuations in profit (Coyle 2007).

Moreover, the production and expansion of biofuels has been cited as a means of achieving the objectives of energy independence, environmental sustainability, and rural development as well as reducing the tax cost of government farm support programs. The potential to achieve these major objectives through a single initiative have often provided further impetus for government intervention. Expectedly, although the evolution of the process of convergence from non-renewable to renewable sources is at diverse stages in different countries, the common element seems to be the active involvement of the state both at the national, regional and provincial levels.

For example, the US government has implemented a wide array of policies to support, encourage and expand the biofuels industry. These measures encompass a broad mix of policy types (grants; tax

[4] The relationship has been examined under varied assumptions e.g. as perfect complements (Vedenov and Wetzstein 2008). Ando et al., (2009) however notes that they may be best regarded as imperfect substitutes given the constraints on the stock of motor vehicles and their capacity for using ethanol.

breaks; lending and credit enhancement programs; regulated mandates; and funding for research, development and demonstration plants), and have targeted multiple points in the biofuels production cycle, including inputs to produce, conversion, distribution, retailing and consumption (Laan et al., 2009). The Renewable Fuels Association acknowledges that renewable fuels are produced only in countries where programs have been created to assist their production (Dinneen 2009).

Other major producers such as Brazil have a history of similar governmental activity through the Proalcool program. This program employed a mix of aggressive market intervention policy tools such as quotas, marketing orders, price setting and subsidized interest rates in order to achieve the objective of stimulating domestic ethanol supply (Martine-Filho et al 2006). Similarly, the Canadian ethanol industry is highly dependent on a myriad of provincial and federal legislation and support instruments. The federal government supports the development of the ethanol industry through a producer credit program, support for ethanol production facilities and research institutions. This is aside from the government's eight E85 (85 percent ethanol) fuelling stations and approximately 800 flexi-fuel vehicles, which can use up to 85 percent ethanol (Government of Canada 2003). The objective is to obtain an ethanol blend ratio in motor vehicles of 5% by 2010 nationally.

Support measures at the provincial level are made up of an array of fuel tax exemptions, content mandates and producer credits. Further, provincial policies are mainly driven by the specificities of their respective economies. For example whilst the governments of Manitoba and Saskatchewan have conciliatory ethanol expansion policies, considering it as a boost to their respective rural economies, the government of Alberta does not encourage ethanol expansion because of the importance of its oil industry (Olar et al., 2004). A review of federal and provincial interventions in the renewable energy sector in Western Canada is presented in the following sections.

2.4.1 Federal Government

Traditionally, Canadian energy policy has been devoted to the development of Canada's large oil, gas and coal resources (Islam et al., 2004). The production of fuel ethanol from agricultural commodities received considerable attention in Canada during the 1980s as a result of falling grain prices and increased environmental awareness (Thomassin et al., 1992). Most of the federal government's initial expenditures in support of renewable energy occurred during that time e.g. the allocation of about $100 million (Canadian) per year to expedite the development of technologies and encourage their market production (Natural Resources Canada 2005). Key decisions were made by the Canadian government in 1992 and 1994 to grant an excise tax exemption for ethanol used in blended fuels (Johnson 1995).

Government support for ethanol in Canada has changed substantially over the last few years (Auld 2008). Olar et al., (2004) noted that the federal government sustained the development of the fuel ethanol industry through an excise gasoline tax exemption and an Ethanol Expansion Program (EEP). The multiyear EEP launched in 2003 funded eleven projects totalling $118 million. Since the EEP, the federal government announced $345 million in funding for biofuel development. In addition, the tax exemption has been replaced by a producer credit program that provides up to 10-cents for every litre of ethanol supplied (Auld 2008). In the 2007 federal budget, $1.5 billion was allocated to support the production of biofuels such as ethanol and biodiesel. This was in addition to the $500 million earmarked for Sustainable Development Technology Canada to invest in the private sector in establishing large-scale facilities for the production of next generation fuels. Other interventions include mandated content requirements of 5% mix ratio of renewable fuels in gasoline by 2010 and 2% renewable content in diesel by 2012.

2.4.2 Province of Manitoba

In 2007, the government of Manitoba passed the Biofuels Amendment Act establishing the legislative framework mandating ethanol in gasoline sold in Manitoba as well as a new incentive structure for ethanol producers (Government of Manitoba 2007). Effective in 2008, Manitoba's ethanol mandate required fuel suppliers in the province to replace at least 8.5% of the gasoline available for sale with ethanol. The Biofuels Act also provided for the establishment of the ethanol fund for the purpose of paying the ethanol grant. Spread over an 8 year period, payments ranged from 20¢/litre (2008-2009) to 10¢/litre (2013-2015). Payouts are however limited to ethanol produced and supplied within the province and are capped by the amount of ethanol required to meet mandated and taxable sales of gasoline. The province is home to two Husky Energy ethanol plants which have a total capacity of 140 million litres of ethanol per year.

2.4.3 Province of Saskatchewan

Aspects of government policy for ethanol are captured in the *Green Print* for ethanol production document. Public incentives for the ethanol industry in Saskatchewan comprise grants, mandates and quantitative allocations. From November 2005 to January 2007 fuel distributors were required to blend 1% ethanol into their gasoline sales (Government of Saskatchewan 2008). This was increased to 7.5% (effective January 15 2007). At the blend rate of 7.5%, the province is expected to use at least 105 million litres of ethanol per year (Government of Saskatchewan 2009). Further, distributors are eligible for a grant of 15¢/litre. Small producing plants i.e. 25 million litres a year or less have a 30% reservation of Saskatchewan's projected consumption (Government Saskatchewan 2009). Five ethanol producing plants are situated in the province.

2.4.4 Province of Alberta

Alberta is often described as a hydrocarbon province because of its strong oil and gas industry. The biofuel sector has however received increased government attention in recent times. The Alberta government is offering three programs to expand bio-energy production in the province. In October 2006, the government announced $239 million in payments to expand the bioenergy production in the province (Government of Alberta 2009). This amount is made up of a Commercial/Market Development Program ($24 million from 2008-2009), a Bio-energy Infrastructure Development Grant Program ($6million from 2008-2009) and a Renewable Energy Credit program ($209 million from 2007-2011). The $24 million Bio-refining Commercialization and Market Development Program provides cost-shared funding for feasibility studies, equipment cost, etc. The $6 million Bio-energy Infrastructure Development Program provides cost shared funding for capital projects. The remaining $209 million is a credit program for Alberta manufacturers of bio-energy. The only commercial ethanol plant in Alberta is Permolex International's facility in Red Deer with a capacity of 40MMly per year.

2.4.5 Province of British Columbia

The government of British Columbia recently pledged more than $32.6 million to commercialize approximately $200 million in provincial renewable energy technology projects. The new clean energy investments will come from two sources: $22.6 million from the Innovative Clean Energy Fund and $10 million to support the production of liquid biofuels with demonstrated low green house gas emissions (Government of British Columbia 2009). The province mandated that by 2010 gasoline and diesel used in British Columbia must contain a minimum of 5% renewable energy content (Ethanol Producer Magazine 2009).

2.5 Role of Government in Ethanol Production

Studies have analyzed various aspects of the role of public policy in the development and expansion of the ethanol industry. Questions bordering on whether these subsidies are the best ways to expend public funds have been raised (Auld 2008). Yacobucci (2006) noted that the incentives given to ethanol producers allow ethanol which has been historically more expensive than gasoline to compete with gasoline and other blending components.

Gorter and Just (2008) used a partial equilibrium framework to analyze the welfare economics of biofuel tax credits and concluded that ethanol policies cannot be justified on the grounds of mitigating the effects of farm subsidy programs. Martinez-Gonzalez et al., (2007) noted that the elimination or at least a reduction of US tariffs on ethanol imports could be beneficial to society. Other studies (e.g. Gardner 2007) that have analyzed the comparative benefits of paying subsidies directly to farmers as deficiency payments as against indirectly as subsidies to ethanol producers conclude that ethanol producers gain relatively more from the latter than the former. These outcomes generally capture the notion that the provision of incentives is better justified based on political objectives than on social welfare maximization objectives.

It has also been argued that government support for ethanol production is justified based on reductions in air pollutant and green house emissions. Literature on the environmental dividends of ethanol production has been divergent with the direction of impact dependent on assumptions of overall fuel use, estimates of vehicle fuel economy, production process efficiency etc. (Viju 2008).Despite the apparent lack of consensus about the prudence or otherwise of governmental incentives for the ethanol industry it is clear that the industry has had a long history of subsidization and other policy interventions across the different countries where a biofuel expansion mandate has been pursued. Secondly, these subsidies cut across virtually every point of the production and marketing of the product. Lastly, such support programs appear to have impacted positively on the growth of biofuel production (Skidmore and Cotti 2009).

2.6 The Value of Distillers Grains as Livestock Feed

The production and marketing of distillers grains remain a key consequence of the expansion of ethanol production not only because of the sheer volumes produced but also its availability as a protein rich animal feed. For example, a bushel of corn weighs 56 pounds and will produce at least 2.8 US gallons of ethanol and 17 pounds of distillers grains (American Coalition for Ethanol 2009). With more grains used for ethanol production more distillers grains are produced. A thirty million gallon per year ethanol plant producing 94,000 tons of Distillers Dried Grain and Solubles (DDGS) per year requires about 180,000 head of livestock eating three pounds each per day to consume the entire stock (Coltrain 2004).

Aside from the volumes produced, the high nutrient content of distillers grains enhances its potential for use as an animal feed. The enhanced nutrient content of the product is a result of the concentration of protein, fat, minerals and vitamins left in grains after the starch has been fermented to produce ethanol. By-products produced mainly from the dry milling process common in livestock feeds come in various forms such as, Condensed Distiller's Solubles (CDS), Wet Distiller's Grains (WDG) and Dry Distiller's Grains (DDG). Other forms are Wet Distillers Grains with Solubles (WDGS; 30%DM), modified (MDGS; 50%DM), or dry forms (DDGS; 90%DM) (Tjardes and Wright 2002). Estimates are varied with respect to the magnitude of concentration of the remaining nutrients in the grains which generally increases by a factor of three (Klopfenstein et al., 2008). Stock et al., (2000), notes that the process of dry milling increases protein from about 10 to 30%, fat from 4 to 12%, neutral detergent fibre (NDF) from 10 to 30%, and phosphorus from 0.3 to 0.9% of dry matter.

This notwithstanding, there are a number of challenges related to the incorporation of distillers grains into livestock and poultry feeds. These include: variation in nutrient content and nutrient availability between batches (within and between plants), co-product handling, storage and transportation, effect on animal performance, end-product quality and nutrient management (Lemenager et al., 2006). The biggest of these challenges for feeders is to know the nutrient content and the digestibility of the source being used (Shurson 2002). Some factors adduced for the observed variability include grain varieties, differences in the types of yeast, fermentation and distillation efficiencies, drying process and the ratio of blending condensed distillers soluble with grains fraction to produce DDGS (Tjardes and Wright 2002).

As a result of these highlighted issues, the potential of by-products as a feed resource across all livestock and poultry industries is the subject of much research. Particular focus is on aspects such as the acceptable level of by-product in livestock rations and the effects of feeding larger amounts of by-product feeds on key measures of animal performance e.g. feed conversion, carcass merits and milk production (Anderson et al., 2008). Different percentages of wet and dried distillers grains have been experimented in the rations of various species of livestock and poultry and the following section examines some relevant literature.

2.6.1 Beef Cattle

Beef cattle are ruminants and are therefore better able to convert fibrous feed and crop residue into meat (Klopfenstein et al., 2008). Mainly fed on forages, research has shown that cattle need supplemental protein to complement the energy in grains and lower protein forages. Distillers grains with or without solubles are a medium protein feed and can be fed as a replacement for protein supplements such as soybean meal, sunflower meal, urea, etc. in beef cattle diets (Tjardes and Wright 2002). A number of studies (e.g. Larson et al., 1993; Vander Pol et al., 2006) have experimented with the incorporation of different amounts of distillers grain in beef cattle rations.

Larson et al., (1993) conducted a number of experiments where WDGS was fed as a protein source or as an energy source. In the former case, WDGS was fed at 5.2% and 12.6% of diet dry matter (DDM) and the latter was at 40% of DDM (to replace supply of both protein and energy). The study concluded inter-alia that WDGS had 35% greater feeding value than corn. Vander Pol et al., (2006) fed 0, 10, 20, 30, and 40 and 50% WDGS as a replacement for corn. Similar conclusions of better feed efficiency were deduced in rations with inclusion rates greater than the 0% WDGS corn control diet.

Trenkle (2003) conducted a 299-day trial with one hundred and ninety two 430 lb Holstein steers to evaluate the response of feeding wet or dry distillers grains to growing and finishing dairy steers. Feeding wet or dry distillers grains did not affect performance except that steers fed 40% wet distillers grains consumed less and had less weight gain, and steers fed 10% wet distillers grains consumed less feed with the same or improved feed efficiency.

Experiments have also been conducted comparing the feeding values of WDGS against DDGS. Ham et al., (1994) performed an experiment with an inclusion rate of DDGS of 40% diet dry matter. They concluded that cattle fed with distillers grains showed greater feed efficiency than corn fed cattle although feed efficiency values were lower for DDGS compared with WDGS. Estimated feeding values were 47% and 24% higher than corn for WDGS and DDGS respectively.

2.6.2 Dairy Cattle

Important considerations in the formulation of diets for dairy cattle are the Ruminally Undegradable Protein (RUP)[5] and Ruminally Degradable Protein (RDP) fractions of the diet (Schingoethe 2008). Nutrient variability of DDGS, especially lysine availability, varies with the quality of the product. Reported values range from a high lysine content of 3.05% of crude protein (University of Minnesota 2008) versus 2.24% of crude protein (NRC Dairy Report 2001).

Al-Suweigh et al., (2002) compared wet versus dried corn or sorghum distillers grains for lactating cows and observed similar production for both wet and dried distillers grains but 6% more milk with corn versus sorghum distillers grains. It can be therefore concluded that nutritionally balanced rations can be formulated that contain 20% or more DDM as distillers grains, although no nutritional advantage is derived when DDGS exceed 20% because such diets may contain excess protein and phosphorus (Schingoethe 2008).

2.6.3 Swine

Distillers by-products have been used in swine diets for more than half a century (Stein 2008). Pigs are monogastric animals and have a lower capability to digest fiber compared to ruminants; reported values are even lower for DDGS compared to corn. This notwithstanding, experiments e.g. Wilson et al., (2003) showed no negative effects of feeding diets containing up to 50% DDGS to gestating sows. Similar results were obtained for lactating sows with inclusion rates of 15% (Hill et al., 2008), 20% (Wilson et al., 2003) and 30% (Greiner et al, 2008). Stein (2008) surmises that DDGS can be

[5] Distillers grains are a good source of RUP, with values usually ranging between 47% and 64% of crude protein for higher quality distillers grains, with WDGS usually 5% to 8% lower than DDGS (Kleinschmit et al., 2007).

included in diets fed to gestating sows in concentrations of up to 50% and up to 30% for lactating sows if diets are formulated based on concentrations of digestible energy, amino acids and phosphorus.

Shurson and Spiehs (2002) listed maximum inclusion levels in swine diets as: nursery pigs (25% of diet), grow-finish (20%), developing gilts (20%) gestating sows (50%), lactating sows (20%) and boars (50%). These recommendations were made under the assumption that high quality DDGS is mycotoxin free. They recommend that no more than 20% should be added to gestation diets and no more than 10% DDGS should be added to lactation diets to minimize the risk of mycotoxicosis, when DDGS is not mycotoxin free. Stein (2008) however posits that all diets containing distillers grains should be formulated in a way such that the concentration of crude protein is greater than in conventional corn-soybean meal diets[6].

2.6.4 Poultry

By-products from ethanol production have higher fiber content than the initial grains feedstock used and is generally considered to be better suited for feeding ruminants. There is however evidence of potential inclusion in poultry diets. It is suggested inclusion of up to 7% or 8% distillers grains and that diets for laying hens could contain up to 10% distillers grain without affecting performance, although feed utilization of broilers tended to decrease when 25% corn DDGS were included in the diet (Waldroup et al.,; 1981 Morrison 1954).

[6] Probably to account for nutrient variability.

A key variable used to determine feed ingredient energy is nitrogen-corrected-metabolizable-energy (Me_n) (Bregendahl 2008). An associated measure otherwise referred to as True ME_n accounts for endogenous energy losses in faeces. Thacker and Widyaratne (2007) using growing broiler chickens, determined the gross and metabolizable energy contents of a single sample of wheat DDGS from fuel-ethanol productions to be 4,724 and 2,387 kcal/kg respectively. Nevertheless, the amino acid content is among the main reasons for including this by-product in poultry feeds (Bregendahl 2008).

Despite the potential to feed large quantities of distillers grain in the livestock feeds, inclusion levels are generally lower than experimented levels especially in the diets of non-ruminants. The typical levels of DDGS (dry matter basis) that can be added to diets have been approximately 20% for beef and dairy, 10% for swine and 5% for poultry (Lemenager, 2006).

2.7 Animal Performance and End-Product Quality

The inclusion of ethanol by-products as feed into animal rations revolves around two broad concerns. The first of which is the nutritional value of these by-products in terms of energy and nutrient digestibility. The determination of the inclusion rate of distillers by-product in diets fed to different categories of livestock that would result in greatest performance, is the other issue. The preceding section examined literature on inclusion rates and nutrient content issues for the various categories of livestock. This section reviews literature on the effect of distillers grains inclusion on end product qualities such as carcass merit, milk production, litter size, egg quality etc. for the different categories of livestock. A survey of the literature indicated that more often than not livestock fed on distillers grains tend to perform better or at least similar to those fed on traditional rations.

Trenkle (2003) in an experiment to evaluate the response of Holstein steers to DDGS concluded that, except for steers fed 40% WDGS that had lighter carcasses, feeding wet or dry distillers grains did not affect carcass weight, area of rib eye, thickness of back fat, marbling, quality or yield grades. Research at South Dakota State University (SDSU), showed that the same quantity of milk production was observed from cows fed distillers grains as supplemental protein as when fed a blend of soybean meal, fish meal and distillers grains (Schingoethe et al., 2002). Further, the research demonstrated increased milk production when cows were fed 5% of the diet dry matter as condensed distillers with solubles. It is therefore concluded that when distillers grains are in the ration, same or greater milk production results is achieved as compared with soybean meal as the protein supplement.

These conclusions are consistent with those of Schigoethe (2001) and Nichols et al., (1998). On swine, Shurson and Spiels (2002) observed that 20% DDGS in swine grow- finish diets has no effect on belly thickness or belly firmness compared to carcasses from growth –finish pigs fed conventional corn-soybean meal diets. On the effect of the by-product on poultry performance, Kerr et al., (2008) noted the absence of any negative effects on egg production and egg quality of laying hens. The study however, observed increased nutrient and dry matter excretion.

2.8 Wheat as an Ethanol Feedstock

Wheat is the ethanol feedstock of choice in Western Canada as the crop performs better agronomically than corn (Austin 2009). Corn is grown in relatively limited proportions in Western Canada predominately in the Red River Valley Region of Manitoba and parts of Alberta (Agriculture and Agri-food Canada 2002). Climatically, the absence of optimal Corn Heat Units (CHU) is a key factor that affects the production of corn in Western Canada (Brown 2009). Despite the development of hybrids with lower CHU requirements, corn production in Western Canada remains small as compared to other grains such as wheat[7].

This aside, the starch content of wheat is highest among the commodities produced in Western Canada, thus further enhancing its suitability for ethanol production (Zijlstra et al., 2007). Different classes of wheat are grown in the region. The 2008 Canadian Wheat Board variety survey indicated that farmers seeded the majority of wheat acres to Canada Western Red Spring (CWRS) and Canada Western Amber Durum (CWAD), with the former being the largest class (Canadian Wheat Board 2009). In Saskatchewan and Alberta these two classes accounted for 88% of total wheat acres whilst CWRS accounted for 81% of total wheat acres in Manitoba. The remaining 12% of the seeded acreage in Western Canada included varieties such as Canada Western Red Winter (CWRW), Canada Prairie Spring (CPS) Red, and CPS White (Canadian Wheat Board 2009).

For ethanol production, wheat varieties with high starch content are desirable. The relatively low starch (high protein) content of the region's dominant wheat class has ensured that a greater percentage of the acreage of wheat in Western Canada is for the purposes of milling – estimated values are as high as 90% (Canadian Wheat Board 2009). Consequently, ethanol plants are turning to low-protein, high starch classes such as soft white wheat, mid protein and mid starch winter wheat varieties and Canadian Prairie Spring (Schill 2008). For example, varieties used at Pound-Maker

[7] In 2008, approximately 25 million tonnes of wheat was produced in Western Canada as against 51 thousand tonnes of corn (Statistics Canada 2009).

Investments Ltd[8] are Canadian Prairie Spring, durum wheat, winter wheat and soft white spring wheat (Biotimes 2006).

In addition to lower protein varieties, ethanol producers are promoting the production of higher yielding varieties in order to make-up for discounted values of the grains. Terra Grain Fuels, a Saskatchewan based ethanol producer, promotes the use of low-protein; high starch varieties such as AC Andrew (a Soft White Spring variety) that can produce 35% higher yields than conventional varieties so that although farmers are paid less per bushel, they could earn more per acre (Terra Grains 2009). Soft white spring wheat is the lowest protein wheat class, containing usually 2 to 3% lower grain protein than Canada Western Red Spring Wheat (Secan 2009). Winter wheat may also be attractive for wheat producers because it out yields spring wheat by 30 to 40% (Schill 2008). Further, growing interest in high feed-type wheat in the ethanol and feed markets has resulted in the creation of a ninth wheat class i.e. Canada Western General Purpose (CWGP) (CWB 2008 Survey). There are currently three winter varieties registered in this class. No data currently exist on this class. Figure 2.2 presents a summary of the 2008 CWB varieties survey.

In practice however, many ethanol plants have a tendency to process a wide variety of wheat classes including red spring wheat, durum wheat, CPS wheat, and others such as soft white wheat and winter wheat (O'Connor 2006). This may be because the ethanol industry in Western Canada is still emerging and the development and adoption of wheat varieties specific for ethanol production still remains nascent. Traditionally, wheat producers in Western Canada produce high-protein wheat that

[8] A Saskatchewan based integrated feedlot/fuel ethanol facility.

commonly garners a premium and therefore ethanol like the feed market might be viewed as an alternative for downgraded wheat (Schill 2008).

The use of a variety of wheat classes in ethanol production potentially poses a number of consequences. Key amongst them is the resultant inconsistency in the nutrient profile of the resulting wheat DDGS produced (O'Connor 2006). Nonetheless, wheat distillers grains have a higher protein content than corn distillers grains -approximately 35% for wheat as opposed to about 27% for corn (O'Connor 2006).

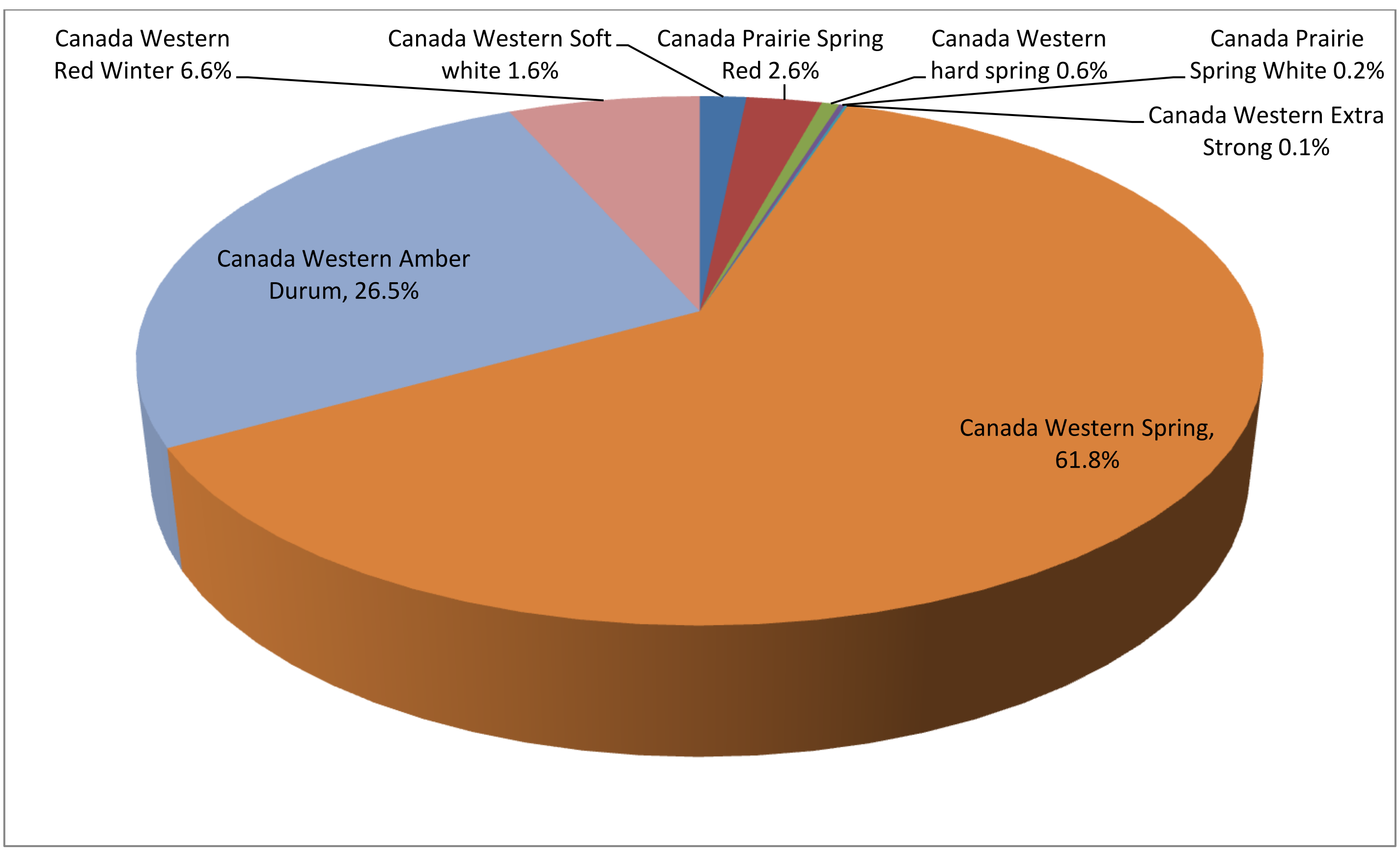


Figure 2.2: 2008 CWB Variety Survey All Wheat- Prairies

Source: Canadian Wheat Board 2008

2.9 Wheat Distillers Grains as Livestock Feed

The dominant feedstock used for ethanol production in Western Canada is wheat, making up approximately 70% of the region's total feedstock utilization. According to Rueve (2005), approximately 360 litres (95 US gallons) and 333kg of DDGS are produced per metric tonne of wheat. This implies that large volumes of wheat DDGS could be produced as ethanol production expands to meet mandated levels. Further, Coltrain (2004) noted that considering revenues from the marketing of DDGS constitute 10-20% of total revenue for ethanol plants, the marketing of the product as a livestock feed becomes critical.

A greater number of the studies done on using distillers grains as animal feed have focussed on corn distillers grain. This is not unexpected considering that corn is the most common grain substrate used for ethanol production due to its abundance and high yield of ethanol (Berg 2004). This notwithstanding a number of studies (e.g. Widyaratne et al., 2008; Nyachoti et al, 2005; Mckinnon and Walker, 2008; Zijlstra et al 2007) have been done on the nutritional value of wheat DDGS. According to McKinnon and Walker (2008), nutrient characterization of a feedstuff can be undertaken in a number of ways. These include the chemical definition of the nutrient content of the feedstuff, examination of feed attributes (i.e. feed palatability, nutrient digestibility etc) and comparison with traditional feeds (McKinnon and Walker 2008).

Present literature therefore can be categorised broadly into three types of studies. Firstly, studies that focus on the assessment of the nutrient profile of wheat distillers grains relative to wheat grains. Secondly, comparative studies of wheat distillers grains with other grain feeds. Thirdly, those that compare wheat distillers grains with corn distillers grains. These experiments have been done with different livestock species measuring feeding effects on varied performance characteristics. Similar to corn distillers grain, the nutrients concentrations such as protein, fat, vitamins, minerals and fiber that remain in the wheat distillers grain are high (i.e. 2-3 fold) relative to the parent grain (Nyachoti et al., 2005; Thacker and Widyaratne 2007).

Widyaratne et al., (2008) assessed the chemical characteristics of hard red spring wheat, Canada Prairie Spring and wheat DDGS. Reported values of crude protein as a percentage of dry matter (DM) were 16.8%, 13.6% or 37.3% for hard red spring, Canada prairie spring and wheat DDGS respectively (Widyaratne et al., 2008). Further, Zijlstra et al., (2007) noted that phosphorus digestibility might be higher in wheat DDGS than in the intact grain. Wheat DDGS has higher levels of dry matter, crude protein, ether extract and gross energy compared with the amounts generally present in wheat (Nyachoti et al., 2005).

Further it was observed that wheat DDGS contains an increased content of Non Starch Polysaccharide (NSP)[9] than wheat. Nyachoti et al., (2005), observed reduced (apparent) digestibility of amino acids for wheat DDGS compared to wheat. Lysine availability in wheat DDGS remained markedly lower than in wheat (Widyaratne et al., 2008). Overall, the macronutrient profile of wheat DDGS is substantially different from wheat; however, some indications exist that the digestible profile of energy, amino acids, and phosphorus makes wheat DDGS a valuable by-product for livestock like swine (Zijlstra et al., 2007).

[9] Increased wheat NSP suggests a reduction in energy digestibility (Zijlstra et al., 1999).

Historically, distillers grains were used as protein feeds and therefore a number of studies have compared its feed value with traditional protein feeds such as soybean meal and canola meal. In recent times however, the ethanol boom with its attendant increased DDGs availability has resulted in the increasing use of DDGS as an energy source especially in feedlot diets (Klopfenstein et al., 2008). Therefore comparative studies of wheat DDGS have included both traditional protein feeds and other grains often used in rations. Gibb et al., (2008) noted that DDGS from wheat have feeding and energy values similar to barley in backgrounding diets.

Thacker and Widyaratne (2007), undertook a comparison of the chemical composition of wheat DDGS and soybean meal and observed lower crude protein (35.7 vs. 47.4%) and metabolizable energy contents (2387 vs. 2440 kcal/kg) in the former relative to the latter. In contrast, as a percentage of total protein, the content of the sulphur containing amino acids methionine and cystine was higher in wheat DDGS than soybean meal (4.64 vs 3.69%) (Thacker and Widyaratne 2007).

Other studies have also compared the nutritional value of wheat DDGS to corn DDGS and blend DDGs (wheat: corn=70:30). Wheat has a similar nutrient profile as corn but has about half the oil content and considerably more protein (National Research Council 1996). As a result, wheat DDGS is typically higher in protein (~40 vs. ~30%) and considerably lower in oil (~5 vs. >10%) than corn DDGS (Gibb et al., 2008). Corn DDGS therefore has a higher energy value than wheat DDGS most likely due to this higher lipid content (Ziljstra et al., 2007). Ortin and Yu (2009) also observed differences among wheat, corn and blend DDGS. Wheat DDGS were lower in sulphur, higher in calcium and phosphorus than corn DDGS but similar to blend DDGS (Ortin and Yu 2009). Although, wheat DDGS may contain a similar NDF[10] content as corn DDGS, the ADF[11] content of wheat DDGS is substantially higher (Zijlstra et al. 2007).

2.10 Effect of Feeding Wheat DDGS on Animal Performance

A key concern with the incorporation of DDGS in the rations of livestock is variability in nutrient content between plants and within batches in the same plant (Swiatkiewicz and Koreleski 2008; Spiehs et al., 2002). This variability in nutrient profile may be attributable to differences in feedstock and processing techniques such as the fermentation conditions, drying methods amongst others (Oconnor, 2008; Belyea et al., 2004). However, wheat DDGS have been included in poultry, swine and cattle diets. Thacker and Widyaratne (2007) studied the effects of wheat DDGS on nutrient digestibility and performance when fed to broiler chicks. They concluded that despite lower digestibility of nutrients in diets containing wheat DDGS, there was no significant differences in weight gain, feed intake or conversion due to its incorporation in the diet. With regards to swine, wheat DDGS may impact carcass quality by affecting dressing percentage, but with correct feed formulation pork and carcass quality may not be affected (Zijlstra et al 2007).

McKinnon and Walker (2008) evaluated the feeding value of wheat DDGS as a replacement to barley in diets for backgrounding cattle. The study found that barley can be replaced by wheat DDGS at up to 40% of the diet in backgrounding rations without any adverse effect on cattle performance (McKinnon and Walker 2008). Gibb et al., (2008) assessed the effect of dried distillers grain from

[10] Neutral Detergent Fiber.
[11] Acid detergent Fibre. Both NDF and ADF are measures of fibre content in feed.

wheat on diet digestibility and the performance of feedlot cattle. They concluded that feeding wheat DDGS did not affect carcass weight, dressing percentage or ribeye area. Walter (2010), observed that like corn DDGS, feeding wheat DDGS did not impact marbling, estimated lean yield and other carcass characteristics.

In summary, wheat DDGS like corn distillers grains represents a nutritious livestock feed. Present literature also indicates that wheat DDGS has a higher protein content relative to corn DDGS, although the latter has a higher energy value. Wheat DDGS has also been successfully included in livestock diets as a replacement for traditional feeds such as soybean meal and barley. The economics of feeding DDGS would depend on availability and price relative to other cereal grains (McKinnon and Walker 2008).

2.11 Economics of DDGS in Livestock Feeding Rations

Present literature on grain-based ethanol encompasses a plethora of issues relating to policy, environmental, nutritional and economic impacts of the production of the renewable fuel and its concomitant co-products. Preceding sections of this study have reviewed some aspects of ethanol production under these identified themes. This section examines studies on the economic effect on the livestock industry with particular reference to distillers grains availability and livestock production economics. Unlike research into other aspects of the ethanol boom, economic evaluation of by-product feeding systems remains for the most part very preliminary (Anderson et al., 2008).

Tokgoz et al., (2006) used a multi-commodity, multi-country system of integrated commodity models to estimate the impact of the continued growth of corn-based ethanol production on the US and world agriculture. The results of the study showed inter-alia that corn used for feed by US livestock may fall by 33% in the long run as a result of the higher feed costs and the resultant shrinking of the industry. Unequal sectorial effects were further observed with pork and poultry being the most affected because of the rigidity in switching from corn-based diets to DDGS based diets. The study was however unable to apportion further breakdown by livestock species because of modelling constraints.

Babcock et al. (2008) updated this study by endogenizing gasoline and ethanol prices, increasing international farm-land production when energy prices rise, etc. A similar conclusion of higher feed cost for livestock producers was derived. The limitation of this approach particularly in reference to the livestock production economics is not dissimilar to Tokgoz et al., (2006). Other researchers e.g. Birur et al., (2008) undertook macro-level analysis using a Computational General Equilibrium (CGE) framework to analyze the growing importance of biofuels for global changes in crop production, utilization, commodity prices etc. According to the study, the total effect of the biofuel drivers was that the medium run market prices for the biofuel feedstock would go up by 9% for coarse grains in the US, 10% for oilseeds in the EU, and 11% for sugarcane in Brazil (Birur et al., 2008).

The three studies cited all suggest that increased demand for grains due to a projected increase in ethanol production could increase the cost of grains for livestock production. Characteristic of such broad based models limited micro-level effects are quantified. There is additional evidence of research assessing the economic benefits of the increasing production of ethanol on individual sectors within the broader livestock industry.

Anderson et al., (2007) evaluated the potential impact of increasing ethanol production on the beef and cattle feeding industries using a partial stochastic simulation model. The partial budget model framework compared feeding returns with or without the inclusion of the by-products i.e. wet and dry distillers grains. The model showed that these co-products would help offset corn prices, as they could be fed at a lower cost of gain than the base ration even for feedlots located 200 to 300 miles from the ethanol plant. Interestingly, rations fed as 15 percent wet distillers grain with soluble (WDGS) with dry rolled corn consistently had the lowest cost of gain whilst 15 percent and 30 percent WDGS fed with steam flaked corn diets consistently had the highest cost of gain. Conclusions were fairly sensitive to assumptions regarding average daily gain (ADG) and to a lesser extent pricing of distillers co-product. For example, the price of WDGS was pegged at 95 percent that of corn (on equal dry matter basis), a change of which could affect the results of the study.

Anderson et al., (2008) analysed various aspects of the US ethanol boom relative to the impact on the livestock industry. In addition to price analyses, the study explored further the work done by Anderson et al., (2007). The feed returns for a Texas and Nebraska feedlot using DDGS (Texas) and WDGS (Nebraska) in rations were simulated. Unlike Anderson et al., (2007) however, prices for the ration components were simulated from a log-normal distribution of prices using parameters (mean and standard deviation) calculated from data spanning the period 2000-2007. Feed conversion rates were simulated from a triangular distribution with the mode taken to be the conversion rate associated with each ration in Anderson et al., (2007). The study concluded that distillers grains were not a cheaper alternative to help producers mitigate the effect of rising corn prices given that prices of the by-product had become correlated with prices of grains over time. Further, the study confirmed the increasing feed cost across the US accentuated the competitive disadvantage of producers in the South relative to those in the Midwest citing reasons of proximity to ethanol plants.

Vander Pol et al., (2006) determined the economic benefit of feeding WDGS relative to feeding a typical high concentrate corn based finishing diets. Energy values, inclusion rates, distance from plant, increased feeding cost and corn price sensitivity impact on economics were also evaluated. It was observed that cattle feedlots had higher net returns with WDGS than without the by-product feed (Vander Pol et al., 2006). Similar to Anderson et al., (2008), the study attested to the competitive advantage of livestock producers located close to ethanol plants relative to others further away. The two studies however differed regards to the conclusions on the impact of the co-product on livestock production. Others such as Jones et al., (2007) examined optimal distillers grain inclusion rate in beef feedlot rations using an optimization model.

All the studies reviewed so far are in relation to the cattle industry. This is because a significant amount of present research studies appears to be in this area. This is not surprising given that the cattle industry remains the largest market for distillers grains Jones et al., 2007). This aside, there is on-going research on the economic impact of the co-product in monogastric rations. A brief survey of current research in this area shows that aside from measuring overall economic benefits, these studies also compared gains between traditional DDGS and some variant forms. For example, Fabiosa (2008) used a standard LP model to solve for 3-least-cost feed rations for finishing hogs, one with no DDGS, a second with traditional DDGS (tDDGS) and a third with the so called newer DDGS (nDDGS).

Based on the ingredient composition in the least cost rations, substitution and displacement rates were derived. The findings suggest that the inclusion of DDGS in a feed ration saves feeder-finisher operations $2.17 per head if tDDGS is used and $8.60 per head if nDDGS is used. Higher substitution and displacement rates were observed for newer-generation DDGS confirming a greater economic value to producers (Fabiosa 2008). Furthermore, the price of the co-product was projected to track corn and soybean meal prices. This observation on the price behaviour of DDGS and corn is not different from that of Anderson et al., (2008).

Bista et al., (2008) estimated and compared the economic value of feed by products (i.e. Iowa DDGS[12] and fractionated DDGS) as ingredients for swine diets from traditional plants and from plants that employed fractionation techniques. Fractionated DDGS showed a higher total diet cost with lower inclusion rate as compared to Iowa DDGS (the traditional DDGS). This cost did not however account for negative impacts of the higher inclusion rate on carcass value in swine. It was noted that if evaluated at the equal inclusion rates that is optimal for fractionated DDGS, diet cost would be higher for Iowa DDGS. The study therefore concluded that despite lower inclusion levels, fractionated DDGS has a higher economic value that Iowa DDGS and should therefore increase net revenue for the ethanol producer (Bista et al., 2008).

From the review, there seems to be ample basis to suggest that the increasing demand for grains to feed the ethanol industry would exert upward pressure on prices over time. Current research generally supports the notion that by-products could serve as a cost saving feed ingredient for livestock producers. The magnitude of these benefits as observed from the literature reviewed tend to be highly dependent on underlying assumptions of pricing, animal performance, inclusion of other factors such

[12] Traditional corn DDGS.

as transportation cost and the form and nutritional value of the product fed. The cited studies all relate to the US market.

Much of the research on issues related to grain based ethanol production in Canada tend to focus on the policy implications both at the provincial and federal level and to a larger extent on the nutritional value of the co-product. Given that the industry in Canada is relatively small, research on the economic implications for the livestock industry is limited, particularly for Western Canada.

This notwithstanding, Mussell et al., (2007) evaluated DDGS supply effect on livestock feeding in Western Canada. The study used linear programming techniques and considered multiple species (i.e. hogs, slaughter cattle, dairy cows) simultaneously. The development of ethanol, feed grain price effects, and the supplies of DDGS were found to have potentially significant implications for western Canadian livestock. Relative to historical information, current information suggests that the effect has been negative from a cost perspective (Mussell et al 2007). Additionally the study highlighted the relative competitiveness of US corn over the locally produced wheat DDGS. A key caveat in the study was the pricing assumptions used for wheat DDGS in western Canada. Wheat DDGS was assumed to be equivalent to the F.O.B Vancouver canola meal price discounted $30/tonne.

The present study uses improved pricing information to examine the impacts of the ethanol industry on the livestock industry in western Canada. Considering that the switching between wheat DDGS and corn DDGS may occur at a tight price margin, using accurate market price information becomes imperative. Further, unlike Mussell et al., (2007), this study uses a disaggregated approach analyzing each livestock (i.e. cattle and hogs) separately. This provides the necessary flexibility to increase the limited price scenarios used in the cited study. Moreover, given differences in industry structure, an aggregated approach has the tendency to crowd the diverse sectorial implications of research outcomes. Mussel et al., (2007) examined the effects from the singular perspective of varying DDGS prices. In a market of continuous price fluidity a much broader perspective is essential. The present analysis therefore examines feed cost adjustments due to changes in other feed grain prices in the presence of DDGS.

The interactions between the Canadian-US grains sector is well documented (e.g. Charlebois and Wensley 2003; Anderson 2000). Given the relationship between US corn and corn DDGS prices (Anderson 2008), assessing the changes in market factors such as transportation cost and exchange rates and the resultant impact on the competitive position of the corn DDGS in rations is a worthwhile exercise.

Chapter 3

Theoretical Framework

3.0 Introduction

This chapter presents the theoretical underpinnings of the presents study. As an economic agent the livestock producer combines inputs to achieve desired outputs. The theoretical framework is therefore developed around the concepts of production, efficiency and optimal producer behaviour. Livestock producer specific output outcomes and the related modifications to traditional producer behaviour are also discussed in this section.

3.1 Theory of Production

Firms represent the economic agents in the productive sector of an economy. The production process, often represented by a production function, describes the transformation of factor inputs into output (Koustoyiannis 2003). This function represents a technical statement of the maximum output that can be obtained through the combination of inputs (Pindyck and Rubinfeld 1998). According to Hall (1998), the generic neoclassical production function for a single output and two variables can be written as:

$$Y = f(x_1, x_2) \quad (3.1)$$

Where:

Y=output

x_1, x_2 =input variables

The number of x_i's is not restrictive to the n=2 limit but can include any finite number of variables. The properties of this production function are specified by the following assumptions (Chambers 1988):

$x_i \geq 0$ and finite (non negative, real inputs)

$f(x_1,x_2)$ is finite, nonnegative, real valued, and single valued for all possible combinations of x_1 and x_2.

$f(x_1,x_2)$ is subject to the "law of diminishing marginal productivity".

$f(x_1, x_2)$ is everywhere continuous and everywhere twice continuously differentiable.

The assumptions ensure the non-negativity of the factor inputs and restrict the combinations of x_1 and x_2 to only one associated maximum y. The property of diminishing marginal productivity implies that as the utilization of a particular input rises, holding all other inputs fixed, the associated marginal increment in output must never increase (Dillion 1977; Chambers 1988).

An important feature of a given production function is how output changes in response to simultaneous input variation. Measured as elasticity of scale ($\boldsymbol{\epsilon}$), it delineates three important characterizations i.e. constant return to scale ($\boldsymbol{\epsilon}$=1), decreasing returns to scale ($\boldsymbol{\epsilon}$<1) and increasing returns to scale ($\boldsymbol{\epsilon}$>1) (Chambers 1988). If a production function exhibits increasing returns to scale, increasing levels of input use results in a greater than proportionate increase in output- a firm has an incentive to build a larger scale of operation. The converse is applicable to the case of decreasing returns to scale. Entrepreneurs are indifferent between centralisation and decentralisation when faced with a production function that exhibits constant returns to scale.

3.2 Efficiency and Cost

By interpreting *y* as the maximum output from the combination of the factor inputs, the neoclassical theory of production implicitly assumes technical efficiency- a firm is technically efficient if it produces the maximum possible output given input quantities (Kumbhakar 1994; Kumbhakar et al., 1991). Other forms of efficiency include allocative efficiency. Allocative efficiency occurs when productive inputs are used in proportions which minimises cost (Coto-Millan 2004). With technical efficiency assumed given, the main objective facing the firm seems to be that of allocative efficiency. Within the context of production this form of efficiency relates to profits or costs. A firm faces the following cost function (Silberberg 1978):

$$C=C(y, w_1,..., w_n) \qquad (3.2)$$

Where y is the output level and $w_1,...,w_n$ are the prices of the factors $x_1,...,x_n$, respectively.

According to Chambers (1988) properties of c(w, y) include the following:

1. c(w, y) >0 for w>0 and y>0 (non-negativity);
2. if $w' \geq w$ then c(w' , y)≥c(w', y)≥ c(w, y) (non-decreasing in w)
3. c(tw, y) = tc(w, y), t>0 (positively linearly homogeneously);
4. if y≥y', then c(w, y) ≥ c(w, y') (non-decreasing in y); and
5. c(w, 0)= 0(no fixed cost).

As discussed in Chambers (1988), the first property ensures that no positive output is produced at zero cost. The second assumption indicates that increasing any input price must not decrease cost. The assumption of positive linear homogeneity implies that as long as input prices vary proportionately, the cost-minimizing choice of inputs do not vary. Stated in this form, the cost function deals with variable cost (long run phenomenon) as implied by assumption six.

The relation (Eqn.3.2) indicates that total cost of production faced by a firm is dependent on the cost of the factor inputs and the level of output. In this form, the linkage between the firm's production and costs at a given technological level is identified. The response of the cost of the firm to changes in output i.e. economies of size is a key derivation from the cost function. Analogous to economies of scale, economies of size measures the cost advantages of centralisation (Chambers 1988). A firm exhibits diseconomies of size when smaller size operations are more cost effective. The reverse is applicable in the case of economies of size.

The existence of this cost function is however predicated on the assumptions regarding the behaviour of the firm. For example the cost function facing a profit maximizing firm is apt to be different from that of a "socialist cooperative" type of firm (Silberberg 1978). Assumptions regarding the behaviour of firms in economic theory is however dependent on the concept of rationality.

3.3 Economic Rationality and Producer Behaviour

Rationality represents the central concept of the economic or rational choice approach. The orthodox conception defines economic rationality by the maximization of exclusively materialistic objective, namely profit for producers and utility by the consumer (Zafiroski 2003). Rationality in this sense is broadly instrumental in that individuals (i.e. economic agents) tend to adopt means oriented towards the satisfaction of their goals (Lagueux 1997). Both consumer and producer theory are fundamentally based on this assumption of economic rationality.

To ensure consistency with this, a number of assumptions are made in both theories. For example, the rational consumer behaviour of utility maximization is frequently analysed under the assumptions of consistency of preference, attitudes of indifference and transitivity. The hypothesis of economic rationality for a firm on the other hand, assumes that firms have knowledge of their production, cost and return functions (Yotopoulos and Wise 1969). Although Mansfield (1985) and Lin et al., (1974) suggest that the notions of "satisficing" and utility maximizing behaviour may be more realistic for some producers, the profit maximizing behavioural assumption is dominant in economic literature. The firm's goal of profit (π) maximization- i.e. maximizing the difference between revenue and cost can be represented mathematically as:

$$\pi = \mathrm{p}f(\mathrm{x}_1,\ldots,\mathrm{x}_\mathrm{n}) - \sum_{i=1}^{n} \mathrm{Wi}Xi \qquad (3.3)$$

Where:

P= output price

$f(x_1 \ldots x_n)$ = output obtained from the combination of factor inputs $x_1 \ldots x_n$.

W_i = price of factor input x_i

x_i= factor input

Koutsoyiannis (2003) lists the two constrained optimization problems facing the firm as:

1. Maximization of profit subject to a cost constraint- i.e. total cost and prices are assumed given.
2. Maximization of profit subject to a given level of output. Output *y* and price *p* are assumed constant.

Thus the firm in production theory is assumed to maximize profits subject to a single production function or to minimize cost subject to a given volume of output (Dorfman et al. 1958). Given that firms do not change output arbitrarily, it necessarily follows that a profit maximizing firm must produce a given level of output at a minimum cost. Silberberg (1978) therefore concludes that the only assertion concerning cost which is consistent with profit maximizing behaviour is that of cost minimization subject to an output constraint:

Minimize $$C=\sum_{i=1}^{n} \mathrm{Wi}Xi \qquad (3.4)$$

Subject to $$f(x_1,\ldots,x_n)=y_0 \qquad (3.5)$$

Where y_0 is an assigned level of output and all the other symbols have the usual meanings. Cost is defined as the cost of an input vector valued at exogenously determined input prices(Fare and Primont1995).

The theory of production related to the agricultural producer tends in most cases to be consistent with the theories of production and optimization outlined in the preceding section. A farm model can include a wide range of production activities representing different crops and livestock products and production techniques (Hazell and Norton 1986). The production options open to the farmer may be restricted by the need to observe sound husbandry practices, self-sufficiency, avoidance of risk, etc. Nonetheless, the agricultural producer combines inputs to produce a desired output and as a rational economic agent, the expectation is that this objective is achieved at the minimum possible cost.

The livestock producer not unlike other producers faces two types of costs i.e. fixed cost and variable cost. Variable costs are the expenses that vary with output within a production period (Greaser and Harper 1994). Examples include expenses on feed, herd health, hourly labour etc. Fixed costs on the other hand do not vary with the level of output. They include depreciation, taxes, interest on investment, land charges, salaried labour and insurance (Greaser and Harper 1994).

Otherwise referred to as operational costs, variable costs are the focus of optimal decision making by farm managers-a key operational cost consideration for livestock producers being feed cost. Variable costs account for the highest cost for producers across the various subsectors i.e. hogs, cattle and poultry. Anderson (2007) noted that feed is the single most costly component of finishing cattle, often representing 70 to 80% of the total cost of gain. According to Hooge and Rowland (1978), the availability of quality feed at a reasonable cost is a key to a successful poultry operation. Similarly, Al-Deseit (2009) approximates the cost of feed to be 60-65% of the total cost of broiler production. Not unlike the cattle and poultry industries, feed cost is a significant item in the cost structure of hog production. According to Fabiosa (2009), as a percentage of total cost of a hog production, feed costs account for around 59%. In an industry where feed cost is a major cost, operating cost increasingly becomes a function of feed price (Guttormsen 2002). To reduce this risk of price variation, livestock producers engage in substitution between feed ingredients.

3.4 Isoquants Factor Substitution and Livestock Feeding

The set of technologically efficient possibilities for producing a given level of output is represented by an isoquant curve. The technique of trade-off or isoquant analysis has been used extensively in production economics in the identification of the minimum cost combination of inputs for given levels of output from a particular firm. Theoretically, for livestock producers, the point of tangency between the feed budget line[13] and the isoquant for a given level of gain represents optimality. The validity of this preposition hinges on key assumptions about the isoquants that includes convexity and negativity of slope (Lipsey and Chrystal 2007). Contrary to traditional economic theory however, empirical derivations of forage/grain trade-offs in cattle feeding (e.g. Goodrich et al., 1974, Brokken et al., 1976) points to some evidence of concavity. Brokken (1977) notes that total energy required for a given gain decreases as the rate of gain increases because fewer days of maintenance are required. As the proportion of grain in feed is increased, replacing roughage, the rate of gain is expected to increase. Hence, grain substitutes for roughage with increasing efficiency.

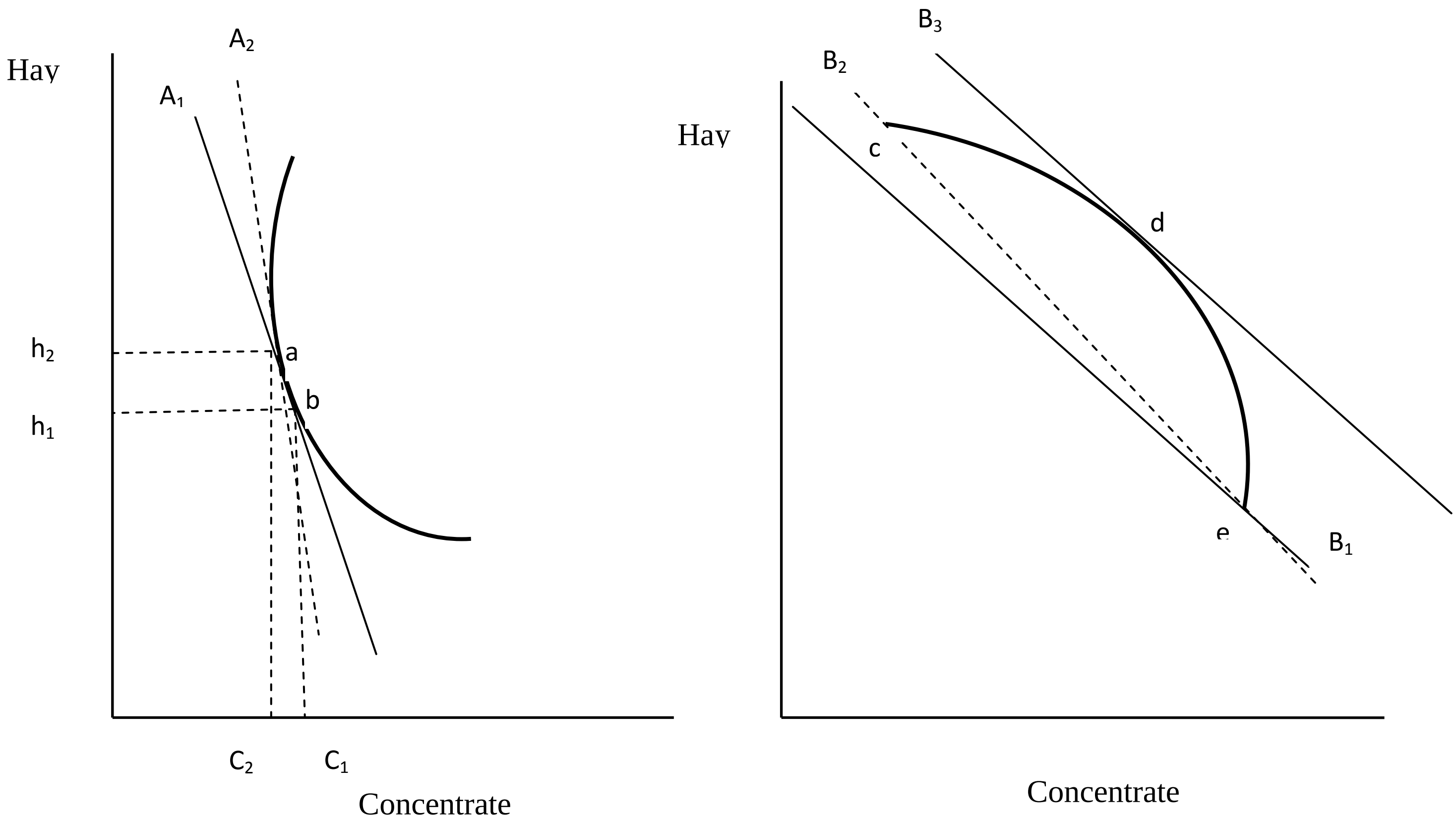
Figure 3.1 shows the two instances of concave and convex isoquants. In the case of the latter, when the price of concentrate increases, the feed budget line becomes steeper (shift from A_1 to A_2 and there is substitution of concentrate for hay). Optimality is achieved at the tangent of the new feed budget line (i.e. point a) and the isoquant representing a given level of gain. In the case of a concave isoquant, the lowest budget line may touch a concave isoquant at multiple points. In this case, B_1

[13] The term is synonymous to an isocost line in traditional economic theory.

touches the isoquant at point *e* whilst budget line B_2 touches at *c* an *e* (Figure 3.1B). Budget line B_3 is parallel to B_1 and is tangent at the highest cost combination necessary to attain the desired output.

Different observations can be made from the case of a concave isoquant. Firstly, a change in the one input could result in the feed budget line touching more than one point on the isoquant curve. Lastly and more importantly, the point of tangency rule produces the maximum cost. The most important implication of concave isoquants is that in general it would not be economically rational to increase the concentrate proportion of a growing diet or the roughage content of a finishing diet in response to changes in price ratio (Brokken and Bywater 1982). Expectedly livestock producers feed grower and finisher diets at different stages of growth. In practice minimum cost solutions are achieved when feed substitution is done within a category of feed ingredients. A producer may substitute canola meal for soybean meal when the former becomes relatively cheaper to attain the same desired level of gain.

Consistent with the theory of production and rational behaviour of the farm firm, minimizing feed cost subject to animal nutrient requirements for a target performance level is fundamental to the economic feasibility of the enterprise. Empirical studies validating the profit maximization (cost minimization) hypothesis often employ the tools of linear programming (LP) and aggregate supply response analysis.



A. Convex Isoquant

B. Concave Isoquant

Figure 3.1 Hypothetical Examples of Convex and Concave Live Weight Gain Isoquants for Roughages and Concentrates with Feed Budget Lines.

Source: Brokken and Bywater (1982)

Chapter 4

Methodology

4.0 Introduction

Feed costs represent the most significant operating cost of livestock producers. Estimates are varied and commonly exceed 50% (Fabiosa 2009; Al-Deseit 2009; Anderson 2007). As such, an assessment of the impact of a new feed ingredient on feeding costs is an integral part of the evaluation of changes in livestock production economics. Historically, agricultural economics research has approached this problem using the tool of linear programming (LP) (Hadrich et al., 2008).

As a system model, linear programming models belong to the *mutatis mutandis*[14] class of models. In this class unlike *ceteris paribus*[15] models, all variables can be adjusted in each iteration and model response ascertained (Charnes and Cooper 1957). The requirements of data accuracy are therefore likely to differ in both cases. Thus, whilst a high degree of absolute accuracy may be necessary in a ceteris paribus study, that for *mutatis mutandis* may be less restrictive (Charnes and Cooper 1957). Aside from this flexibility in data requirements, the wide availability and reliability of software, good algorithms and practitioners' understanding of the power and scope of LP models make them a fundamental planning tool (Sen and Higle 1999).

An LP model is defined by the maximization or minimization of a linear function, called the objective function, which is dependent on a set of decision variables restricted by various linear restrictions

[14] Means the necessary changes having been made.
[15] Means all other things being equal.

often referred to as constraints (Darmon et al., 2002). These constraints may be equalities or inequalities. Aside from applications in the diet problem, transportation, activity analysis and optimal assignment analysis represent some of the other applications of LP models.

The diet problem entails the selection of the least cost combination of feeds that meet a specified level of nutritional requirement for livestock. An LP model is well-suited to this kind of problem that includes a single performance measure or objective (to minimize feed cost) and constraints (here the nutritional requirements of the animal) (Wachemheim and Mattson 2002). Resolving the diet problem therefore represents one of the most successful applications of the LP paradigm (Romero and Rehman 2003). A compendium of studies (e.g. Bennen and Hoffman 1989; Wachemheim and Mattson 2002 etc.) exists in economic literature that applies LP models to derive least cost rations for various livestock species. This procedure depends on the following assumptions (Romero and Rehman 2003):

i. There is a single objective (usually the minimization of the cost of the diet) which is a mathematical function of the decision variables.
ii. The decision variables of the problem are the amounts of the variable ingredients that constitute the diet.
iii. The nutritional requirements are convertible to mathematical functions of the decision variables which form the constraint set of the problem.
iv. The optimum diet is the one that minimises the single specified objective without any violation of the constraints imposed.

Assumption one (i) does not necessarily have to hold in all cases. There is evidence of studies that incorporate for example environmentally compliant manure nutrient disposal cost into least-cost livestock ration formulation (Hadrich et al., 2008).

4.1 Model Specification

An LP least cost ration formulation in algebraic terms has the following specification

(Tozer 2000):

$$\text{Minimize } T = \sum_{j=1}^{n} CjXi \qquad (4.1)$$

$$\text{Subject to } \sum_{j=1}^{n} aijxj \leq (\geq, =) bj \qquad (4.2)$$

$$xj \geq 0 \qquad (4.3)$$

Where:

T= total cost of ration

Cj= cost of ingredient j

*X*j= quantity of ingredient j in the ration

aij= the quantity of the nutrient in ingredient j,

bj =the required amount of nutrient *i* in the ration; the equality or inequality of the constraint is determined by the nutrient of interest.

4.2 Assumptions

A number of assumptions about the nature of the production process, the resources, and activities are implicit in the linear programming model (Hazell and Norton 1986). These are as follows:

1. Optimization: it is assumed that an appropriate objective function is minimized.
2. Fixedness: At least one constraint has a non zero right hand side coefficient.
3. Finiteness: It is assumed that there are only a finite number of activities and constraints to be considered so that a solution may be sought.
4. Determinism: All c_j, a_{ij}, and b_j coefficients in the model are assumed to be known constants.
5. Continuity: It is assumed that resources can be used and the activities produced in quantities that are fractional.
6. Homogeneity: It is assumed that all units of the same resource or activity are identical.
7. Additivity: The activities are assumed to be additive in the sense that when two or more inputs are used, their total product is the sum of their individual products.

With the exception of assumption four (4) most of the listed assumptions are widely accepted as valid. The assumption of determinism i.e. where all parameters are assumed known with certainty has often been questioned in empirical studies in the area of livestock nutrition (e.g Sen and Higle 1999; Zhang et al., 1996). To account for nutrient variability, the incorporation of a safety margin (SM), the adjustment of the right hand-side constraints and stochastic programming (SP) have been some approaches adopted (Tozer 2000). In terms of the first two approaches, the concentration of nutrients in the ration formulation is increased. With SP models, variation is built into the mathematical structure of the problem. Other approaches suggested include the linearization of the variance function using Taylor's approximation or direct approximation (Rahman and Bender 1971).

Although the SP model seems to be the most precise of the listed approaches, there are some questions relating to its application and it seems to ignore the decision-makers' risk assessment (Zhang et al., 1996; Tozer 2000; Rahman and Bender 1971). Moreover, at a desired probability of 50% both the conventional linear programming and stochastic programming models yield the same results (Zhang et al., 1996). Furthermore, given the computational flexibility of the conventional LP model, the levels of a nutrient of interest can be varied over a range of values and the model response ascertained. In light of this, the present study adopts the conventional LP framework.

4.3 Other Attributes: Shadow Values

For most linear programs the solution of the primal problem (i.e. cost minimization) comes with other values. The interpretation of these values usually gives an indication of the robustness of the model. One such result derivable from a given optimal solution is shadow prices. Defined as the rate of change of an objective function from a unit increase in its right-hand side (Bischop 2009). Shadow prices are referred to as dual values in some instances. However, Ho (2000) opined that such equivalence between dual variables and shadow prices holds only under the assumption of non-degeneracy[16].

[16] An LP is degenerate if in a basic feasible solution, one of the basic variables takes on a zero value.

In many applications involving linear application problems, the shadow prices may be at least as important as the solution to the problem. This is because they allow the model user to determine whether certain potential changes in the original requirements might actually increase the objective function (Aucomp and Steinberg 1982). Sections of Pesti and Miller's (1993) discussion on some forms on shadow values are presented below:

i. Most LP programs provide information indicating the extent to which the cost of a feed ingredient has to fall before it becomes feasible for inclusion in diets. Subtracting this cost change referred to as marginal cost change from the current ingredient cost results in the shadow price of the ingredient. An ingredient not included has a zero (0) shadow value.

ii. On the nutrient side, a change in ration cost with a change in a nutrient constraint is referred to as the shadow price of the nutrient.

A key part of the present analysis focuses on the shadow values of the feed ingredient cost, with specific reference to that of distillers grains. This is to provide an understanding of the economic value of the feed ingredients in the various rations.

4.4 Sensitivity Analysis

An important analytical attribute of most linear programming applications is the ability to undertake post-optimality analysis. For least cost rations, this is usually accomplished by changing the cost, nutrient composition, and constraint of some ingredient of interest and re-running the formulation. A plot of costs at different prices, referred to as price maps, can be obtained from these estimations.

Sensitivity analysis is not only limited to changes in market prices, but it also allows for the examination of the changes in factors that impact on prices. The present analysis examines different scenarios of variation in feed ingredient prices particularly the effect of the cost of transportation on corn Distillers Dried Grains with Solubles (DDGS) prices and the assessment of the impact it has on the competitiveness of corn distillers grains in the rations of various livestock species.

4.5 Price Analysis

The use of DDGS as livestock feed is not new to the feed market (Klopfenstein et al., 2008). The present concern is in relation to the potential of the co-product to partly offset the demand driven increase in the prices of grains. In the case of Western Canada it is expected that wheat DDGS could partially offset the demand driven increase in wheat prices as wheat based ethanol production expands. In livestock rations, distillers grains can be used as an energy source or as a protein source (Coltrain 2004). Distillers grains with or without solubles are of medium protein and can be fed as a replacement for other proteins in beef cattle diets (Tjardes and Wright 2002). The by-product has also been fed in diets replacing barley and corn (Tjardes and Wright 2002; Gibb et al., 2008). Thus, the economics of feeding distillers grains is dependent on both grain prices and the availability and price of protein (e.g. canola meal) (Dhuyvetter et al., 2005). The behaviour of DDGS prices relative to that of other traditional feed grains is therefore a relevant empirical question.

The present study analyzes the behaviour of both wheat and corn DDGS prices relative to traditional feed prices i.e. canola meal and feed barley prices in Western Canada. There is presently limited historical data on wheat DDGS prices in Western Canada. This paucity of data results from the fact that the longest running wheat ethanol plant in the region (i.e. Pound-Maker Agventures Ltd) has had the practice of using its distillers grains to feed livestock which form a part of its integrated commercial livestock feeding system. Other plants, e.g. Terra Grain Fuels and North West Terminal, are fairly new in the market. As a result, researchers have adopted approximation methods to estimate wheat DDGS prices. Mussell et al. (2008) derived the price of wheat DDGS in Western Canada by discounting the F.O.B Vancouver canola meal price by $30/Tonne.

According to industry sources (Holman 2009), historically, there are many factors which determine the pricing of DDGS. Wheat distillers grains can either be sold as a protein or energy source. In times when there is a shortage of protein, wheat DDGS trades at values closer to other protein sources such as canola or soy meal. At other times when there is an abundance of protein, wheat DDGS will compete with feed barley for pricing. Therefore it is suggested that a better approximate price for wheat DDGS may be an average of the Lethbridge feed barley cash price and the F.O.B Vancouver canola meal price[17] (Holman 2009). The present study therefore adopts this approximation approach.

To further explore the relationship between wheat DDGS, corn DDGS, feed barley and canola meal prices, a Vector Autoregressive (VAR) model is used. Vector Autoregressive models are often used to analyse dynamic relations among a set of interrelated economic variables (Korol and Lariviere 1998). A number of macroeconomic studies (e.g. Morrissey et al., (2002); Yeboah et al., (2009) etc) have used the VAR framework to analyse different economic trends. Further, VAR models have been used in analysing both intertemporal and spatial price relationships of agricultural commodities.

[17] Less $45 for rail freight and terminal charges.

Rapper et al., (2009) used a VAR model to determine the nature and the extent of spatial price relationships among distinct regions in the U.S. fresh peach wholesale market. The study found statistical evidence of differences in price relations among regions. Vollrath and Hallathan (2006) tested the integration of the US-Canada meat and livestock markets. As part of the analysis a VAR model was used to assess the dynamic motion of market correctedness. The VAR analysis showed among others that there is connectivity in the Canada-to-US hog market but not vice versa. Anderson et al., (2008), analysed the price relationship between corn DDGS and corn in the US. A Vector Error Correction Model (VECM) was estimated separately for two time periods i.e. 1982-1988 and 1989-2007. The study found a closer relationship between DDGS and corn in recent times than in the past.

Questions about the theoretical basis of some aspects of the VAR analysis have been raised. For example, Lence and Falk (2005) criticized the use of the VAR model in spatial market analysis. It has been however noted that as a medium of analysis, the VAR model is tractable and is easily shown to be a reduced form of the representation of structural economic models providing a useful framework for the investigation of both short and long run relationships (Morrissey et. al 2002).

Further, using the framework to model price relationships enables researchers to test the hypothesis of lead/lag relationships of the long-run market integration (Rapper et al., 2009). The present study therefore applies the VAR model in an intertemporal framework to analyse the relationship between distiller's co-products and other feed grains. It is repeated for corn DDGS. The analysis is similar to that of Anderson et al., (2007). Unlike Anderson et al., (2007) however the present study pertains to feed price behaviour in Western Canada.

A general representation of the VAR model in levels is shown in Lutkepohl (2007):

$$Y_t = A_1 Y_{t-1} + ... A_p Y_{t-p} + u_t \qquad (4.4)$$

Where:

- t = time (t=1,...T)
- Y_t= an nx1 of economic variables in this case feed prices
- P = is the lag order
- A_i(i=1,...p) are (k×k) parameter matrices
- U_t~ idd (0, $\sum_u$)

In the presence of cointegration, a Vector Error Correction Model (VECM) is used. A VECM specification of the series may be stated as:

$$\Delta yt = \delta + \prod y_{t-1} + \sum_{i=1}^{p-1} \emptyset \Delta yt\text{-}1 + \varepsilon i \qquad (4.5)$$

Where:

yt is a matrix of feed prices

δ is the intercept term

$\prod y_{t-1}$ is the long run

$\sum_{i=1}^{p-1} \emptyset \Delta yt\text{-}1$ represents short run dynamics

ε_i is the error term

4.6 Approaches in Estimating Cointegration

The Engle and Granger (Engle and Granger, 1987) and Johansen (Johansen 1988) approaches to estimating cointegration are common approaches used in econometrics literature. A cointegration relationship exists if a linear combination of integrated variables is stationary. The cointegration vector defines the long-run relationship among the non-stationary variables i.e. deviations from this long run equilibrium will be temporary and market forces will bring variables to their cointegrated equilibrium.

4.7 The Johansen Approach to Cointegration Analysis

Introduced by Johansen (1988), the method employs two tests i.e. the Trace and Maximum Eigen Value (MEV) statistics tests both of which are likelihood ratio tests to determine the number of cointegration equations given by the cointegration rank, r. Whilst the trace statistics tests the null hypothesis of r cointegration relations against the alternate k cointegration relations where k is the number of endogenous variables, the MEV statistic tests the null hypothesis of r cointegrating vectors against the alternative of r+1 cointegrating vectors.

When r=1, the Johansen single equation dynamic modeling and Engle-Granger approaches are both valid. When r > 1 however, the Johansen approach is preferred over the Engle-Granger approach for two major reasons. First, in the multivariate case considered here, it avoids the identification problems one may encounter with the Engle-Granger approach if there is more than one co-integrating vector. Second, the Dickey-Fuller test employed to test for cointegration in Engle-Granger regressions too often rejects the existence of equilibrium relationships (Kremers et al., 1992). The present study examines price interrelatedness and reports results for unit roots, cointegration and VECM/VAR results.

4.8 Market Potential Estimation

Key factors that affect the expansion of ethanol production include the large available supply of relatively low priced feedstock, as well as sufficient numbers of livestock to provide a reliable market for distillers grains (Dhuyvetter et al., 2005). Further, given that revenue from distillers grains constitute 10-20% of the gross revenue for ethanol producers, a good market for the product becomes imperative especially as margins tighten (Coltrain 2004). The marketing of distillers grains is affected by a number of factors. The price of competing feeds affects the value of the by-product, as does the market for the livestock that consumes the distiller grains (Laan et al., 2009). This implies that the growth of ethanol production in Western Canada and the resulting increase in the availability of distillers grains has implications for both the livestock industry and the marketing of traditional feed products. This section presents the methodology for estimating the potential market for distillers grains in Western Canada.

Estimates of market size for DDGS are not uncommon in the present literature (e.g. Cooper (2005); Togkoz et al., (2007); Dhuyvetter et al., (2005); Berger and Good (2006)). All of the cited studies were done in relation to the U.S. market. The present analysis considers only products from the dry milling process since it is the dominant production process. Three main forms of distillers grains are obtainable from this process i.e. Distillers Dried Grains with Solubles (90% dry content), Wet Distillers Grains with Solubles (WDGS) (30-35% dry content), Modified Distillers Grains with Solubles (50% dry content). The present study assumes that all distillers grains marketed to the livestock industry are in the form of DDGS. This is because the majority of this co-product has been dried and sold as distillers dried grains (Cooper 2005).

An estimate of the DDGS market size requires information about DDGS inclusion rates, animal populations, and adoption rates (Dooley 2008). Berger and Good (2006) and Dhuyvetter et al., (2005) summarized the literature for DDGS consumption for dairy, cattle, hogs and poultry. This study adopts the inclusion rates of Berger and Good (2006) in line with the notion that they are reasonable given current technology for approximating upper limits of DDGS market potential (Dooley 2008).

4.9 Data and Data Sources

Data on adoption rates in Western Canada was unavailable and therefore the analysis assumes a 100% adoption rate[18]. Data on livestock populations was obtained from Statistics Canada. Daily intake rates and days fed/year values were adopted from Good and Berger (2007). However, daily

[18] Factors such as the farm size, proximity to ethanol plants etc. May affect the rate of adoption, this assumption examines the upper limit scenario.

feed intake for beef cattle was adjusted based on advice from animal scientists (.i.e. Walter 2009; Racz 2009) to reflect practices in Western Canada. Ruminant category is restricted to beef and dairy. The estimation implicitly assumes that nutritionally optimal inclusion is equivalent to economically optimal inclusion levels.

Monthly F.O.B. Vancouver canola meal price data for various years was obtained from the Cereals and Oil Seeds Review published by Statistics Canada. Additionally, average monthly feed wheat and western feed barley (Lethbridge cash bids) in Canadian dollars per tonne were used. The average monthly data was computed from weekly price data obtained from the Alberta Department of Agriculture and Rural Development. Monthly average prices for soybean meal were estimated from the Vancouver F.O.B. weekly cash prices (CAN$/tonne) published by the Market Services Division of Agriculture and Agri-food Canada. Data for time series i.e. canola meal, barley, feed wheat, corn DDGS and wheat DDGS prices span a 10-year period i.e. January 2000-June 2009.

Monthly price data on the prices of corn DDGS were obtain from the United States Department of Agriculture's Feed Grains Database (location: Lawrenceburg, IN). Prices were converted from US$/short ton to US$/metric tonne to ensure a common basis with Canadian measurement units. Monthly noon Canadian dollar exchange rates sourced from the Bank of Canada were used to convert prices to CAN$/tonne. According to Gabert (2009) a good freight estimate from the US (i.e. Lawrenceburg) to Western Canada (i.e. Lethbridge) by truck is CAN$50/tonne[19]. All US corn DDGS prices were therefore adjusted by CAN$50/tonne to account for freight. Corn DDGS price data for

[19] Sensitivity analysis in LP modelling allows for a variation of this estimate.

August 2000-2004 were unavailable as was data for September 2002 and 2003 as well as that for November and December 2007. To ensure uniformity in the time series analysis, the prices of the other feed grains in the corresponding months were omitted.

Prices of supplements such as limestone and minerals were relatively constant and therefore current prices were used (McKinnon 2009; Armstong 2009). Ten year monthly average (2000-2009) hay and barley silage prices published by the Agricultural Financial Service Corporation (AFSC) in Alberta was used in the present analysis. For the hog rations, weekly prices of feed peas for Lethbridge from October 2009-January 2010 published by the Alberta Canola Producers Commission was used.

Chapter 5

Results and Discussion

5.0 Introduction

The results of estimation approaches used in the study are presented in this chapter. The projected output of wheat DDGS in Western Canada derived from ethanol production capacity and ethanol to DDGS conversion factor is first outlined. Secondly, an estimate of the potential market is derived to assess the extent of market deficit or surplus. Trade and import demand analysis complete the first part of the macro-level analysis. The results of time-series analysis of price interrelatedness are also presented. The last section of the chapter is an outline of the linear programming results for beef cattle and hogs. These two sectors are selected because they represent the largest potential ruminant and monogastic markets respectively.

5.1 Projected Wheat DDGS Output

According to Natural Resources Canada (2009), Western Canada accounts for about 32 per cent of Canada's gasoline consumption. Assuming that an equivalent percentage of ethanol will be required to attain mandated blend ratios, this translates to 640 million litres per year (.32×2 billion litres). Production data obtained from the Canada Renewable Fuels Association (2009) indicates that production capacity for wheat based ethanol production is in the region of 490 million litres per annum. Estimates are varied as to the amount of ethanol that can be produced from a tonne of wheat. Racz (2007) posited that approximately 365 litres of ethanol is produced from the dry milling of a tonne of wheat. An estimated yield of 360 l/tonne was used by Rueve (2005).

The present study adopts Racz's (2007) estimate of 365 l/tonne of wheat. This implies that approximately 1.34 million tonnes of wheat (490 million litres divided by 365l/tonne) may be needed to produce the required volumes of ethanol. As a by-product, distillers grain tracks the growth in ethanol capacity. Each tonne of wheat produces approximately 290 kg of DDGS, implying that 388,600 tonnes of wheat DDGS per year could be produced in Western Canada. This estimate may however be on the high side against the backdrop of the fact that some ethanol producers use corn depending on price advantages. Hence, subject to competitiveness of wheat based ethanol production relative to corn, the concomitant production of wheat DDGS may be lower than estimated values.

From Table 5.1, the potential market for DDGS in Western Canada is about 2 million tonnes per year. This estimate is sensitive to the following underlying assumptions. Firstly, the assumption of a 100% adoption rate of distillers grains may be unrealistic because large size farms are more likely to have a higher rate of adoption of distillers grains than smaller ones because of economies of size advantages in terms of lower handling and transportation cost (Dooley 2008). Secondly, actual feeding rates may be less than feasible levels. Lastly, estimates are highly sensitive to assumptions about daily intake values and days on feed. This notwithstanding, the important finding is that livestock numbers in Western Canada are sufficient to consume the increasing co-products of a growing ethanol industry.

From the above analysis, it can be concluded that the estimated production of wheat DDGS based on current production capacity data of 388,600 tonnes is lower than the estimated potential demand of 2 million tonnes. The key implication of this deficit is that the import market would be an important source of DDGS for the Western Canadian livestock industry when relative prices dictate that feeding the product is economically beneficial.

Table 5.1: Western Canada Livestock Inventory Numbers and Potential DDGS Consumption

Livestock Class	Western Canada Head#(000 head)	Daily intake(lbs DDGS/day as-fed)	Days fed/yr	DDGS consumed (lbs/head/yr)	Total DDGS(000 tonnes/yr)
Beef cows	3973.000[1a]	3.00	90	720.00	1297.50
Dairy cows	235.500[1b]	4.50	365	1642.50	175.50
Breeding swine	608.800[2a]	1.20	310	372.00	102.70
Market swine	4377.200[2b]	0.50	365	182.50	362.30
Broilers	29803.780[3a]	0.02	56	1.12	15.10
Layers	12971.685[3b]	0.030	365	10.95	64.40
Total					2017.50

[1a, 1b] Cattle inventory data, Statistics Canada, 2009

[2b, 2a] Swine inventory data, Statistics Canada, 2009

[3a, 3b] Poultry data obtained from 2006 Census, Statistics Canada.

All figures on animal numbers represent a summation of individual provincial data for British Columbia, Alberta, Saskatchewan and Manitoba.

5.1.1 Marketing of Domestically Produced DDGS

Aside from plants such as Pound-maker Inc. that feeds distillers grains on-site, distillers grains produced in Western Canada are marketed to dairy, hog and cattle operations. Three forms of sales arrangements are identifiable in the distillers grains market. Some transactions are done through the use of fixed price contracts, whilst others employ floating price contracts tied to a benchmark (Holman 2009). Spot price markets are also not uncommon.

Ethanol producers in Western Canada convey the distillers by-product from the production site to the livestock producers via different modes of transportation. These include, rail, trucks and mini-bulk bags loaded on flat-deck trailers. For example Terra Grains Fuels[20], uses trucks and railcars to deliver distillers grains to customers. Factors such as the loading rate and the capacity of these trucks may therefore likely influence the cost of the by–product. For livestock producers, economies of size put larger farms at a more advantageous position in terms of ability to access and use distillers grains. These farms incur relatively lower transactions cost because of their ability to purchase, store and use bulk quantities. Furthermore, they are more likely to take on longer term agreements (Holman 2009).

5.2 Trends in DDGS Trade

Potential supply of DDGS into Western Canada could be from two main sources. Firstly, through inter-regional trade with other provinces and territories within Canada[21]. Lastly and most importantly, through external trading partners particularly the United States. In 2008, the total distillers grains produced in the US amounted to 22 million metric tonnes (Deutscher 2009). With conservative

[20] A Saskatchewan based grain ethanol producer.
[21] Presently, intra-regional trade in DDGS is not significant.

projected production levels of approximately 44 million metric tonnes per year, the export market could be an important secondary market for US distillers grains (CARD 2007).

In 2008, 4.5 million metric tonnes of distillers dried grains was exported from the US, with Canada being the largest export market after Mexico (Deutscher 2009). Canada also exports distillers grains to the US, however the balance of trade favours the US. Figure 5.1 shows trends in the trade of distillers grains between Canada and the United States. Currently, under both US and Canadian trade product labelling, distillers grains are categorised broadly under brewers' and distillers dregs and waste. The figure plots the volumes of Canada's monthly exports and imports of distillers dregs and waste over a 10 year period (2000-2009).

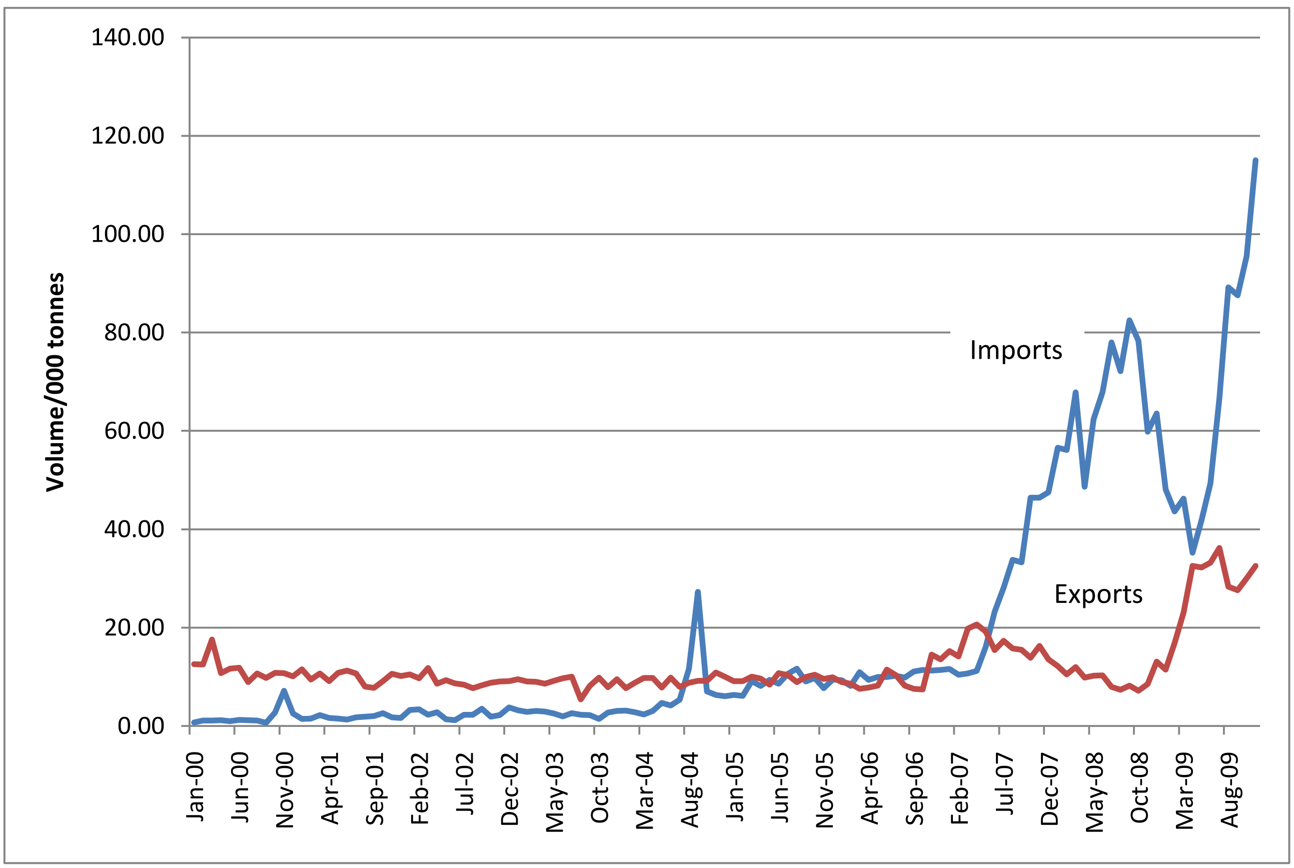


Figure 5.1 Canada: Trade in Distillers Dregs and Waste with the US

Source: United States Department of Agriculture's Feed Grain Database (2010)

The trend in the importation of US DDGS have been increasing since 2006. In 2008, Canada imported 772,000 tonnes of US distillers grain, up 453,000 tonnes from 2007 (Smith 2009). A number of both demand and supply side factors may have accounted for this trend. On the demand side, poor climate conditions and the resultant poor crop conditions in Western Canada are important considerations (Slozka 2009). Other factors including transportation cost, exchange rates, etc. could also have played a role. For example, the value of the Canadian dollar has been appreciating against the US dollar over the relevant period (i.e. 2000-2009). Worth approximately 63 cents/US$ in April 2002, the Canadian dollar experienced a 63% increase in value reaching a high of 1.03CAD$/US$ by November 2007. Despite depreciating to values below 90 cents/US$ between October 2008 and July 2009, the value of the Canadian dollar has been appreciating in recent times. Figure 5.2 shows the trends in the Canada/US noon exchange rates from 2000-2009.

The conventional notion is that as the dollar appreciates, imports become relatively less expensive and therefore the volume of imports tends to increase. Expectedly, imports of distillers grains from the US (i.e. Figure 5.1) seems to mirror Figure 5.2- higher volumes of imports corresponds with higher values of the Canadian dollar and vice versa. On the supply side, increasing production of ethanol in the US is a key factor especially given that the production of distillers co-product tracks the production of ethanol.

The present analysis provides a regional breakdown of distillers grain imports from the US, except in the years 2000 and 2004[22], importation of distillers by-product into Western Canada has been

[22] Other years have also decreased from previous years however the overall trend is increasing.

increasing. Particularly significant is the consistency in the increase after 2004. Figure 5.3 illustrates the value of import demand of distillers by-product in Western Canada as a percentage of total value of distillers by-product imports from the US to Canada over a 10-year period.

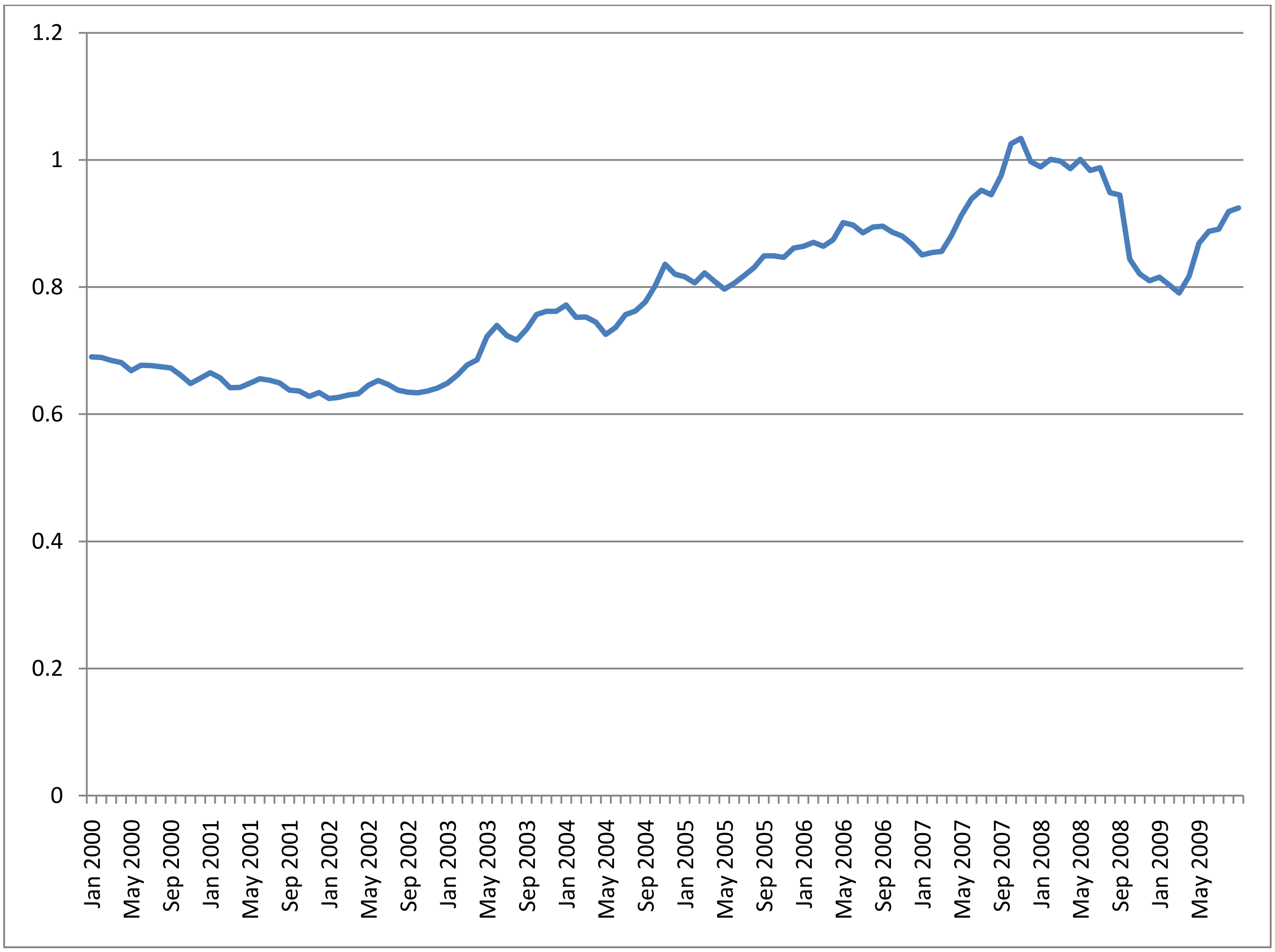


Figure 5.2: Trends in Canada/US Noon Exchange Rates

Source: Bank of Canada 2010

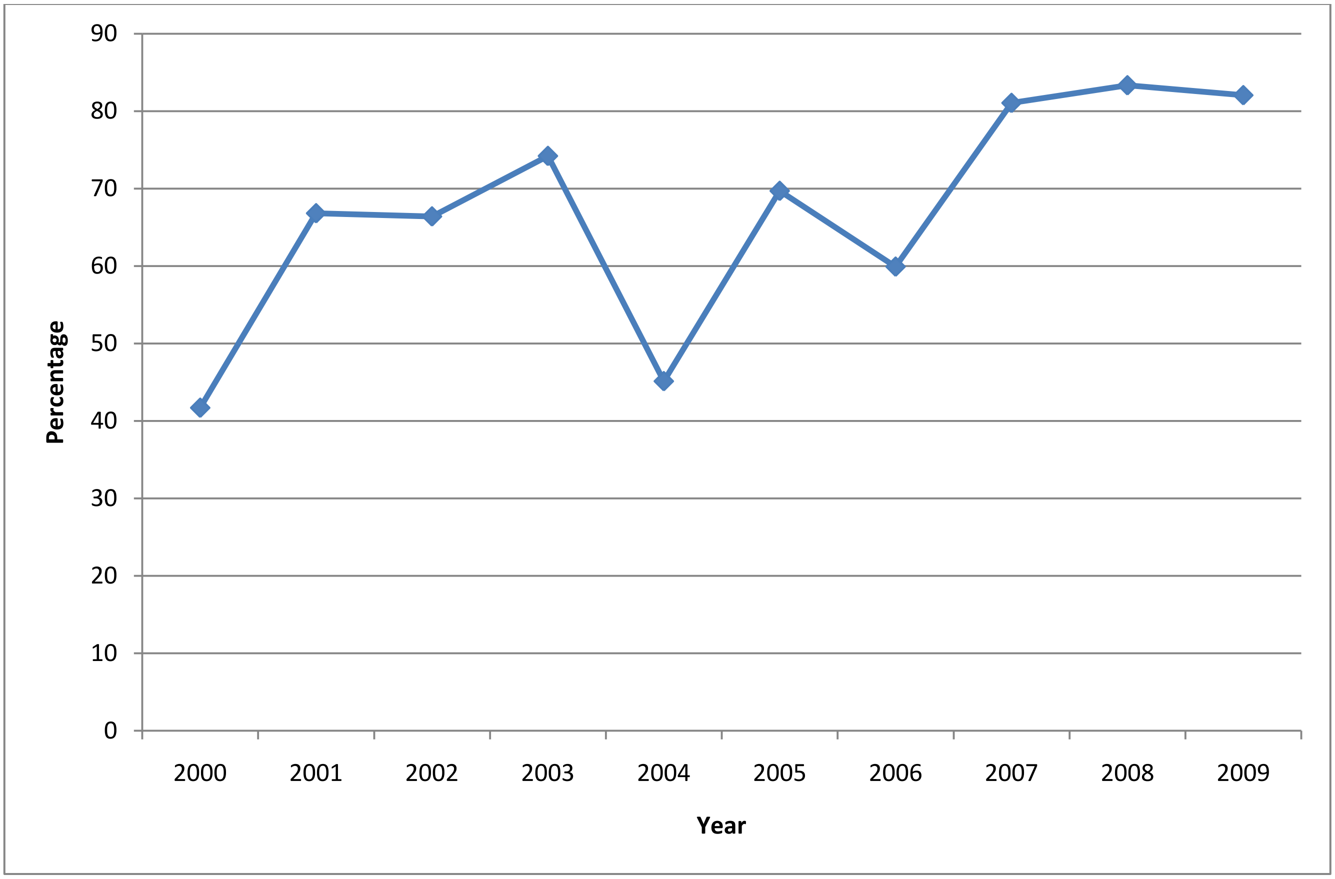


Figure 5.3 Western Canada's Distillers By-Product Imports as a Percentage of Total Canadian US Distillers Imports

Data source: Industry Canada (2009)

Provincial import demand is further analyzed, expectedly Alberta's imports have consistently increased since 2005. Alberta's large cattle population (6.3 million head) resulting from the practice of feeding most cattle to finish whilst competing for feeder cattle from the other provinces could account for the high demand for distillers co-product (Brown, 2009; Government of Alberta 2009). Present literature indicates that DDGS inclusion rates are highest among cattle than any other livestock species. Other factors such as climatic conditions affecting the production and the availability of traditional feed grains are also likely to impact the importation of DDGS. Figure 5.4 provides a provincial break-down of the value of US co-product imports in Western Canada.

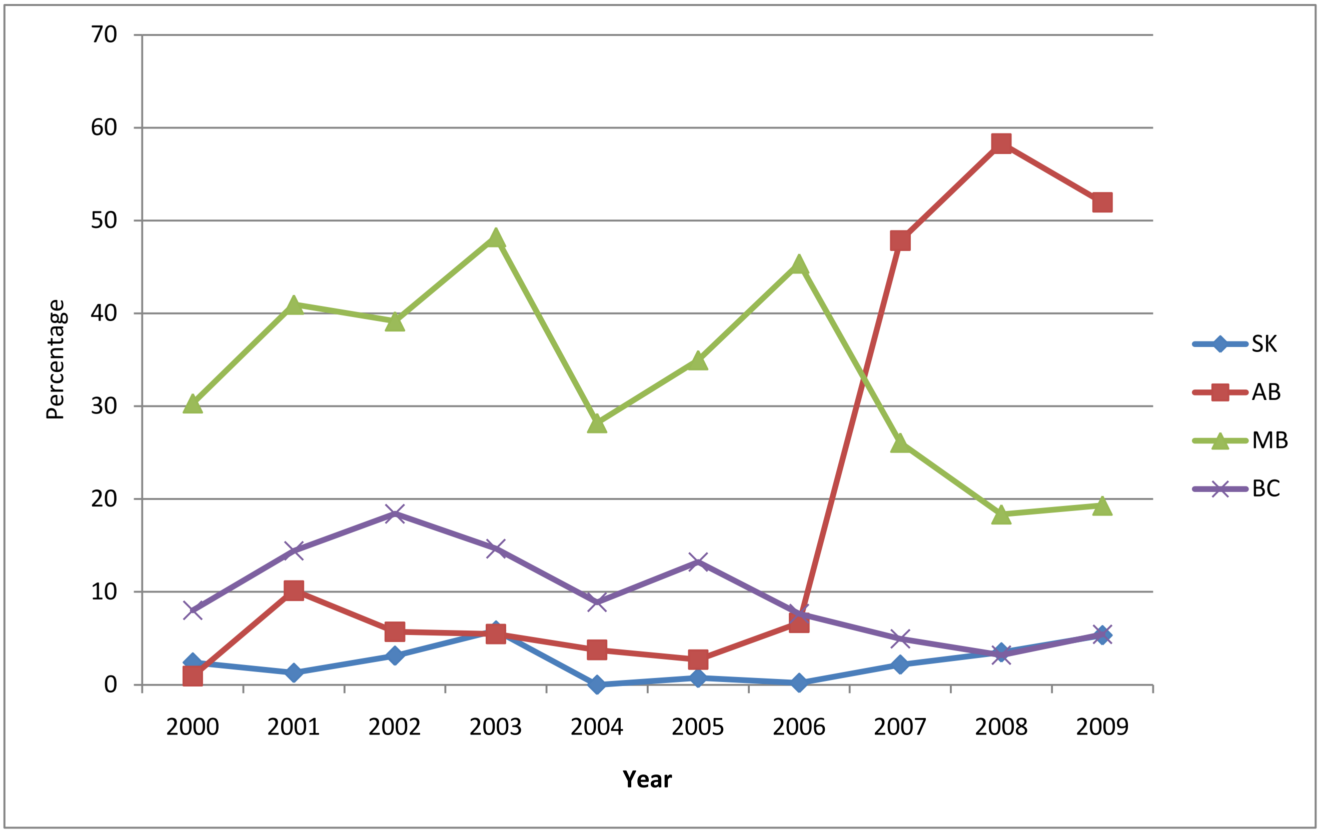


Figure 5.4 Western Canada: Provincial Imports of U.S. Distillers By-Products

Data Source: Industry Canada (2009)

5.3 By-Product Price Behaviour

A key attribute of feed prices is the continuous fluidity in the trends of prices over time. The conventional notion is that the availability of distillers grains could potentially offset part of the increases in traditional feed grain prices. This section analyzes the behaviour of the price of both types of distillers grains i.e. corn and wheat relative to canola meal and barley prices. Figures 5.5 and

5.6 show the trends in the price of wheat DDGS as a percentage of traditional feed barley and canola meal prices.

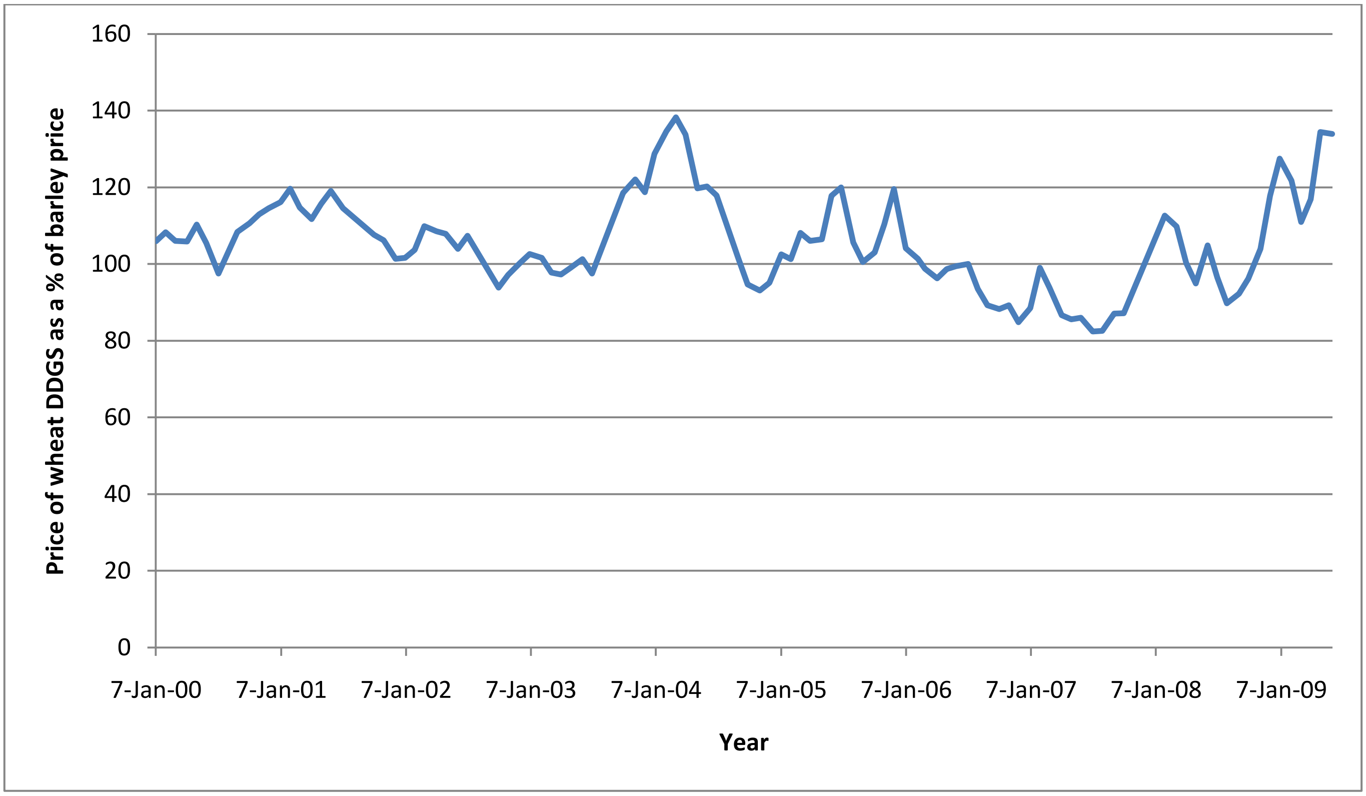


Figure 5.5 Wheat DDGS Price as a Percentage of Feed Barley Price

Data adapted from Alberta Department of Agriculture and Rural Development (2009).

The price of wheat DDGS as a percentage of feed barley and canola meal show different trend patterns over time. Generally, a lower percentage is desirable as compared to a higher level if DDGS are to substitute significantly in rations. This implies that *ceteris paribus*, it may be more advantageous to replace a feed priced 50% of another than for example, 140%. Comparing Figures 5.5 and 5.6, the value of wheat DDGS relative to canola meal tends to be considerably lower than that of feed barley averaging 75% for canola meal as against 106% for feed barley. Further, whilst the value of wheat DDGS as a percentage of the price of canola meal has trended downwards in recent times whereas the inverse seems to be the case for feed barley. This suggests that it may be relatively more advantageous to introduce the co-product as a replacement for the higher protein canola meal than barley.

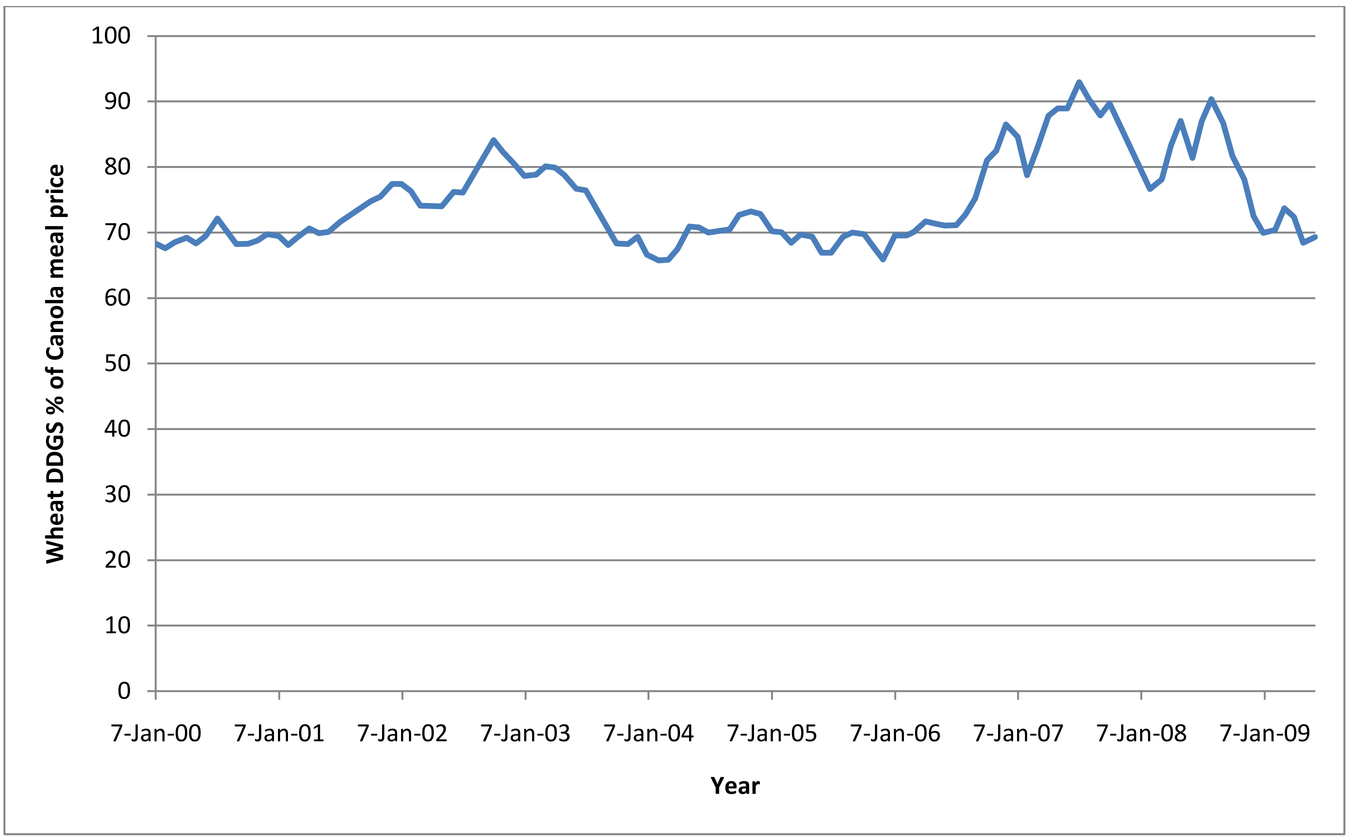
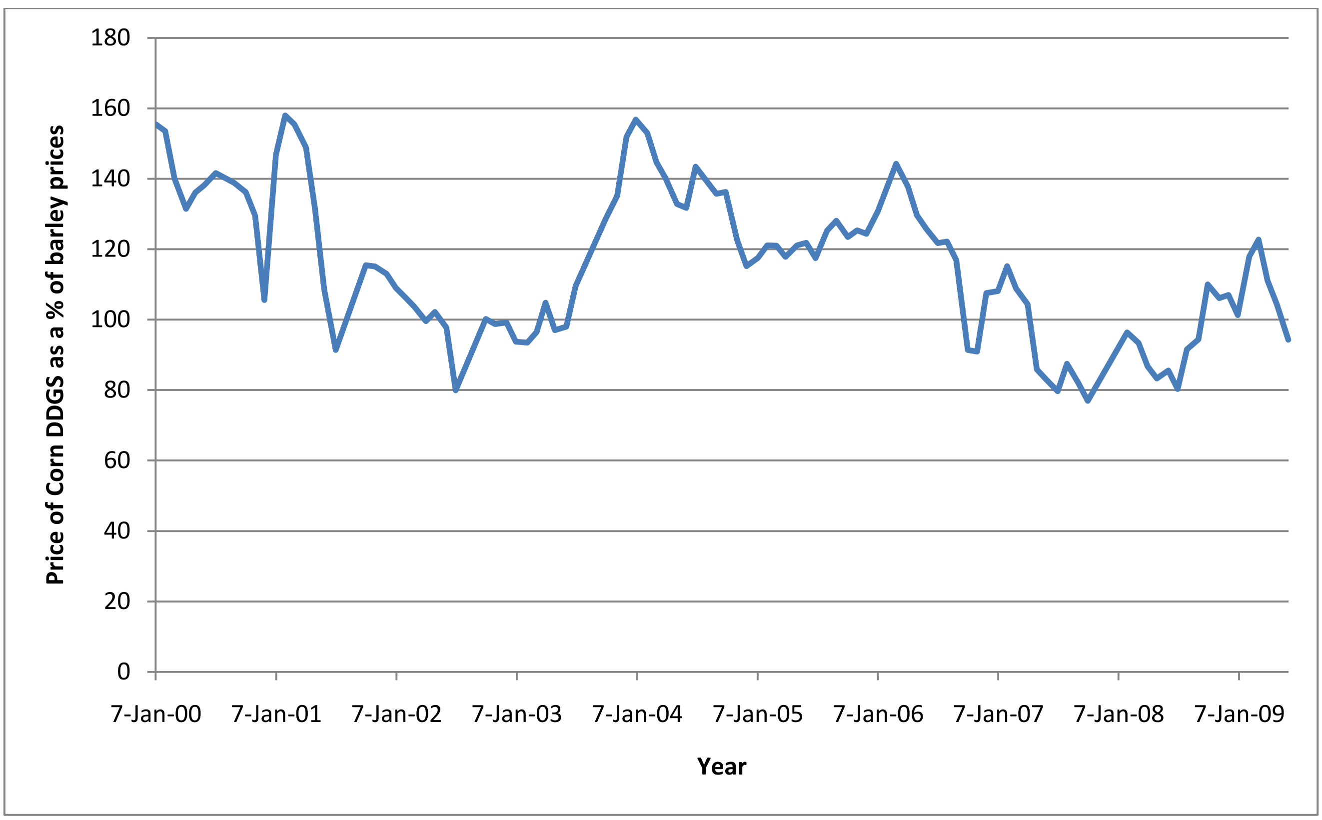


Figure 5.6 Wheat DDGS Price as a Percentage of Canola Meal Price

Statistics Canada (2009c).

Given the increasing use of US corn DDGS in Western Canada especially after 2006, the present study replicates the analysis in the preceding paragraph for US corn DDGS. Trends are shown in Figures 5.7 and 5.8.

The key observations from the trends (Figures 5.7 and 5.8) are two-fold. Firstly, the price of US Corn DDGS as a percentage of canola meal prices shows considerable variability over time. Secondly, the price of US corn DDGS as a percentage of canola meal and barley prices has been trending downwards in recent times although mean values are marginally higher i.e. 82% (vs. 75% for wheat DDGS) and 116% (vs. 106% wheat DDGS) overtime for the former and latter respectively. Similar deductions about relative values for canola meal and barley can be made- distillers grains represent a cheaper substitution for canola meal than barley.



5.7 Corn DDGS Price as Percentage of Feed Barley Price

Data adapted from Alberta Department of Agriculture and Rural Development (2009), USDA Feed Grain Database (2010).

This analysis suggests that US Corn DDGS may be becoming more competitive in recent times. A poignant point of the present analysis is the volatility in the feed price relations. The subsequent section of the present study therefore estimates interrelatedness between the distillers by-product and the prices of feed barley and canola meal.

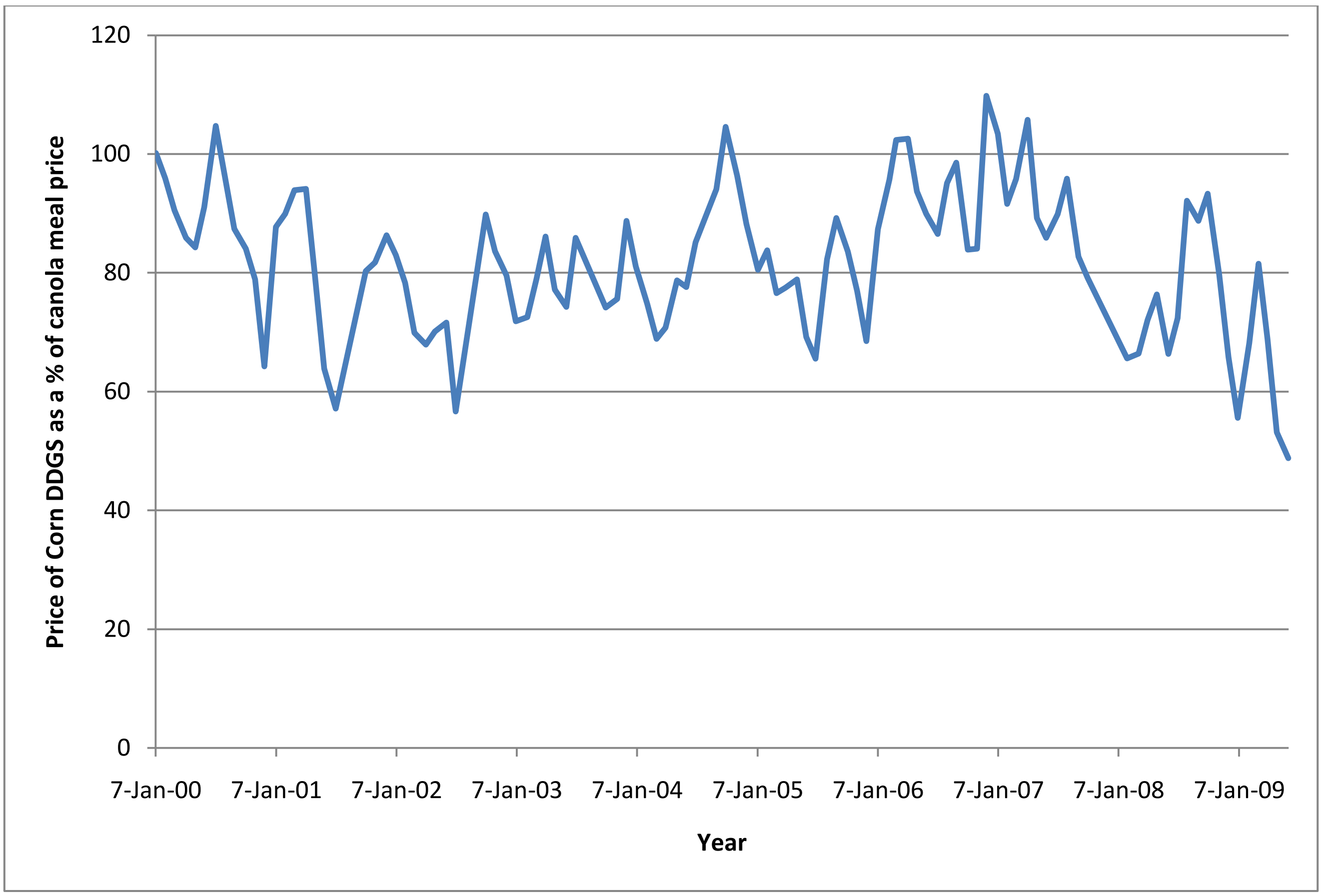


Figure 5.8 Price of Corn DDGS as a Percentage of Canola Meal Price

Data adapted USDA Feed Grain Database (2010), Statistics Canada (2009c).

5.4 Cointegration Analysis

Cointegration analysis is used to measure price interrelatedness between distillers grains, canola meal and feed barley prices. A precursor to the analysis is to test whether the individual price series have unit roots. Various stationary tests have been developed to test for statonarity. The Augmented Dickey Fuller (ADF) test (Fuller 1976, Dickey and Fuller 1979) and the Phillips-Perron (PP) test (Phillips 1987, Phillips and Perron 1988) represent popular approaches used in economics literature. The present study adopts the ADF approach[23]. The results indicate the presence of unit root in all the price variables when tested in levels. P_{fBt} , P_{WDDGSt} ,P_{canola} , represent prices[24] of feed barley, wheat DDGS and canola meal respectively. This implies that all the variables are non-stationary in levels. The ADF test was repeated for the variables in first difference and the null hypothesis of non-stationary was rejected in all instances. All variables are therefore integrated of the order 1 i.e. I (1) process. The results are shown in Table 5.2. The ADF test is repeated for corn DDGS, where P_{CDDGSt} represents the price of corn DDGS. For the purposes of uniformity the 5% significance level is used for all tests.

A basic requirement for time series modelling is that the series under the study must be weakly stationary, i.e. it has a constant mean and covariance (Liew et al., 2005). As a general rule non-stationary time series should not be used in regression models so that to avoid the problem of spurious regression. However, there are important cases when a linear combination of two I(1) processes results in a stationary process. According to Lutkepohl (2007), if yt ~I(1) and the variables

[23] Schwert 1989 found that relative to the ADF, the PP test is more size distorted (reject I (1) null much too often when it is true) if Δyt has an Autoregressive Moving Average representation with a large and negative Moving Average component.

[24] All nominal feed prices were deflated by an Implicit Price Deflator.

are potentially cointegrated, the levels form of the VAR may not be the most useful representation because it does not contain the cointegration relations explicitly and these relations are often of particular interest. The present analysis proceeds to test for cointegration between wheat DDGS prices and the other price variables in a bivariate framework. Additionally, the test is repeated for corn DDGS. The Johansen procedure is used. The results of the Trace and Maximum Eigen Test statics are shown in Table 5.3. Both tests confirm the presence of one cointegration between variables at the chosen significance levels.

Table 5.2 Augmented Dickey Fuller (ADF) Test Results for Wheat DDGS

Variables(in levels)	Null Hypothesis	T test statistic	P-Value	Inference
P_{fBt}	Unit root	-2.149	0.5125**	I(1)
$P_{canolat}$	Unit root	-1.805	0.6955**	I(1)
P_{CDDGSt}	Unit root	-3.242	0.0822**	I(1)
P_{WDDGSt}	Unit root	-2.223	0.477*	I(1)
Variables in first difference				
ΔP_{fB}	Unit root	-6.31	0.000*	I(0)
$\Delta P_{fcanola}$	Unit root	-8.078	0.000*	I(0)
ΔP_{WDDGS}	Unit root	-7.252	0.000*	I(0)
ΔP_{CDDGS}	Unit root	-9.969	0.000*	I(0)

* Significance at 1% **significance at 5%

Table 5.3 Results of Cointegration Tests for Wheat and Corn DDGS

Hypothesized No. of CE’s	Variables	Trace test statistic	Max-Eigen Statistic
None At most 1*	P_{WDDGS}: P_{barley}	13.26 5.20	8.06 5.20
None At most 1*	P_{WDDGS}: P_{canola}	12.71 5.26	7.45 5.26
None At most 1*	P_{CDDGS}: P_{barley}	11.18 4.14	7.04 4.14
None at At most 1*	P_{CDDGS}: P_{canola}	13.84 4.19	9.65 4.19

*Denotes the rejection of the hypothesis at the 0.05 level

Tables 5.4 and 5.5 report the estimates of the long run relationship between the prices of corn and wheat DDGS, barley and canola meal prices. From Table 5.4 the prices of corn DDGS show evidence of positive interrelatedness with the price of canola meal and feed barley. Further, the speed of adjustment parameter indicates that the drive towards the long-run equilibrium is induced by corn DDGS prices[25]. This result is unsurprising, considering previous research done in the US (e.g. Anderson 2008) found positive interrelatedness between US corn and DDGS prices. Moreover, given the established price linkages between US corn and Western Canadian grain prices, the price relationships observed from the VECM analysis may be a result of an indirect effect of US corn prices.

Not unlike corn DDGS prices, wheat DDGS prices showed evidence of long-run positive price interrelatedness with canola meal and barley prices. Dissimilar to corn DDGS however, the

[25] For example the significant adjustment coefficient of 0.45 indicates a short run adjustment of 45% per period towards the long-term equilibrium

adjustment coefficients were not significant at the desired levels. This may imply that the adjustment to long-run equilibrium is induced by an external factor possibly US corn prices.

Table 5.4 Error Correction Estimates for Corn DDGS

Variable	Coefficient		Variables	Coefficient	
$P_{CDDGS}(-1)$	1.000		$P_{CDDGS}(-1)$	1	
$P_{CANOLA}(-1)$	0.472*** (0.06954)		$P_{BARLEY}(-1)$	0.349* (0.20191)	
Constant	0.619		Constant	1.040	
Speed of Adjustment	$\Delta(P_{CDDGS})$ -0.45032*** (0.10386)		Speed of Adjustment	$\Delta(P_{CDDGS})$ -0.228*** (0.07039)	
	$\Delta(P_{canola})$ 0.1494 (0.16648)			$\Delta(P_{BARLEY})$ -0.03954 (0.03954)	

*** Significant at 1% level, ** significant at 5% level, * significant at 10%

Table 5.5 Error Correction Estimates for Wheat DDGS

Variable	Coefficient		Variables	Coefficient	
$P_{WDDGS}(-1)$	1.000		$P_{WDDGS}(-1)$	1.000	
$P_{CANOLA}(-1)$	0.723*** (0.14641)		$P_{BARLEY}(-1)$	1.319*** (0.29387)	
Constant	0.0439		Constant	0.364	
Speed of Adjustment	$\Delta(P_{WDDGS})$ 0.016384 (0.10386)		Speed of Adjustment	$\Delta(P_{WDDGS})$ -0.0395 (0.06184)	
	$\Delta(P_{canola})$ 0.135246 (0.16857)			$\Delta(P_{BARLEY})$ 0.0553 (1.443)	

*** Significant at 1% level, ** significant at 5% level, * significant at 10%

The price analysis has a number of key implications. It can be deduced that the relative prices of DDGS have trended downwards overtime. Secondly in terms of relative price behaviour, DDGS seem to represent a cheaper replacement for protein feeds (i.e. canola meal) than the other feeds. Lastly, the VECM model showed linkages between distiller's co-product and other traditional feeds in western Canada. This implies that over time the prices of these feeds trend in the same direction although they may deviate from each other in the short run. The key implication of this result is that prices of co-product may become cheaper in relative but not absolute terms over time.

The caveat in the present analysis relates to the fact that comparatives are based solely on price behaviour without any consideration for the feed value of the feeds under consideration. In addition, results are highly sensitive to the underlying assumptions about wheat DDGS price approximations. The next section presents results from feed ration analysis that incorporates both price and feed value considerations in estimating the economic value of wheat and corn DDGS in Western Canadian livestock rations.

5.5 Results from Linear Programming Model

Least cost rations were formulated for different livestock species in different growth stages. These rations were then assessed under the different scenarios of distillers grains availability, freight margin rate variation and substitute ingredient price variation. The changes in relative feed ration cost and the competitiveness of distillers grains is noted under the various scenarios. Rations were run using General System Inc.'s Feed Formulation System. Ease of usage, computational flexibility and availability of options such as parametric analysis are the main reasons that informed choice of this LP program. To undertake such analysis information on feed grain prices, nutritional composition of feed grains and diet specifications are required. Table 5.6 presents a descriptive summary of prices used in the various estimations. Standard deviations for key feed ingredients are reported in addition to their average values. This is to provide reasonable limits for sensitivity analysis. Appendix B, C and E report the resultant nutrient compositions of the cattle and hog rations.

5.6 Beef Cattle Backgrounding Diet Specification

The production of slaughter-ready beef cattle generally comprises several stages including cow-calf, growing and finishing. This section focuses on backgrounding (grower) diets. Backgrounding normally involves feeding smaller calves a grower ration to prepare them for a finishing ration at a feedlot (Yambayamba and Price 1991). A grower ration contains a higher proportion of forage and is designed to increase frame size while adding little fat (Perillat et al., 2003). Table 5.7 is a typical beef backgrounding diet specification.

Table 5.6 Descriptive Summary of Price Data

	Price/Tonne	Standard deviation
Barley	156.09	35.73
Canola meal	206.00	46.40
Corn DDGS	163.79	24.12
Barley silage	32.90	7.31
Wheat DDGS	153.13	36.89
• Min	100.05	
• Max	246.44	
Hay	82.31	22.58
• Min	55.35	
• Max	137.85	
Limestone	105.00	
Dicalcium phosphate	900.00	
Field Peas	185.50	
Soybean meal	320.18	
Canola Oil	783.29	
Hog-min-Vit	580.00	

Source: USDA Feed Grain Database (2009); Alberta Canola Commission (2009); AFSC (2009) Agriculture and Agri-food Canada (2009).

Table 5.7 Backgrounding Diet Specification

Nutrients	minimum level	maximum level
Crude Protein (%)	13.00	15.50
T.D.N (%)	66.50	69.50
Calcium (%)	0.60	0.80
Phosphorus	0.25	0.40
Barley silage		90

Source: McKinnon (2009)

5.6.1 Base Ration (no DDGS)

Least cost formulations were run under the scenario of prohibitively high distillers grains (corn and wheat) prices. This was to capture the case of DDGS unavailability and to enable comparisons in diet composition and cost when the co-product is introduced into the diet. Results are reported on as fed basis[26].

The LP model reports the percentages and weights of the selected feed ingredients in the least cost ration in addition to the price ranges. The reported price range gives an indication of the rate of substitutability among feed ingredients. A feed ingredient with a wider range may be viewed as exhibiting considerable rigidity in the diet as against one with a closer range. Negative values are reported in some cases because values are not restricted to non-negative numbers. Aside from this, the cost and shadow values of feed ingredients not selected are also reported. The difference between these two i.e. market cost and the shadow value otherwise referred to as the marginal price change for

[26] The feed cost values are converted to dry matter basis for the cattle rations

use gives an indication of the extent to which the price of a given feed ingredient must fall in order to become economically feasible for inclusion into the diet. The greater the shadow value relative to the market cost of the feed, the higher its economic value and the greater the possibility of being selected for inclusion into the least cost ration. An ingredient that is included has a shadow price of zero.

The base ration (Table 5.8) is predominately barley silage (54%) and barley (21%). The total cost of the diet is $75.49/tonne as fed. However from the total percentage of diet and weight of feed, 100 units of Dry Matter (DM) are in 167.63 units of weight. Converting to dry matter basis: (100/167.63) = 0.5966% DM. Hence cost/tonne on DM basis = (total cost as fed/% DM) =
(75.49/0.5966) = $126.53/tonne on DM basis. Similar conversion of feed cost to DM basis is done for all the cattle rations.

The relative shadow values of wheat DDGS and corn DDGS are $175.11/tonne and $182.09/tonne respectively. Given that the actual prices of wheat DDGS and corn DDGS are $153.13/tonne and $163.79/tonne, the latter with its higher energy content seems to represent a more competitive feed in beef background diets relative to the former. To validate this assertion, the model is re-run with the actual price values of distillers grains under separate scenarios.

5.6.2 Availability of Wheat DDGS

The least cost ration is estimated assuming the availability of wheat DDGS. The co-product with its high protein content replaces the protein supplement i.e. canola meal and partly replaces some of the barley (barley reduces from 21.29 to 15.95%) in the base ration. The crude protein content of the diet increases from 13 to 15.50% (Appendix B[27]). Diet cost however reduces from $75.49($126.53/tonne DM basis) to $74.77 ($125.16/tonne DM basis). Savings made amount to approximately $0.72/tonne ($1.37/tonne DM basis).

Table 5.8 Beef Cattle Backgrounding Base Ration Results

Ingredient	Percent	Weight	Cost	Low	High
Barley	21.29	35.69	156.09	107.84	166.08
Canola meal	3.49	5.85	206	191.51	1043.34
Limestone	0.58	0.98	105	-97.35	851.07
Barley silage	53.69	90.00	32.90	0	34.87
grass hay	20.95	35.11	82.31	77.09	111.26
Totals	100	167.63	12.73		
			Total Cost=$75.49		
Not selected	Cost	Value			
wheat DDGS	1000	175.11			
corn DDGS	1000	182.09			
Dical Phos	900	15.95			

Table 5.9 Beef Cattle Backgrounding Ration Results (Wheat DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Barley	15.95	26.70	156.09	148.66	212.36
Wheat DDGS	10.06	16.83	153.13	11.72	160.84
Limestone	0.62	1.04	105.00	-90.13	1495.69
Barley silage	53.77	90.00	32.90		34.60
grass hay	19.60	32.81	82.31	77.73	108.49
Totals	100.00	167.38	12.52		
			Total cost=$74.77		
Not selected	Cost	Value			
canola meal	206	183.69			
corn DDGS	1000	166.72			
Dical Phos	900	18.74			

[27] Appendix B reports the nutrient composition of the various Beef backgrounding rations estimated.

5.6.3 Availability of Corn DDGS

The least cost ration is estimated assuming the availability of corn DDGS. Wheat DDGS is kept at a prohibitively high price. Relative to the results of the base ration (Table 5.8), corn DDGS replaces canola meal and the percentage composition of barley also reduces by about 50% (from 21.29% to 10.69%). This is unsurprising considering the relatively higher energy value of corn DDGS. Expectedly, the crude protein content of the corn DDGS base ration is lower (i.e. 15.146%) as compared to (15.50%) in the wheat DDGS based diets. It appears that the higher economic value of the corn DDGS is in respect to its higher energy value as expressed by the replacement of higher proportions of barley.

Diet cost further reduces to $74.43/tonne ($123.15/tonne DM basis), $0.34/tonne ($2.01/tonne DM basis) less than the wheat DDGS diet. Compared to the base ration however, savings on total feed costs amounts to approximately $1.06/tonne ($3.38/tonne DM basis). Results of a third scenario examining the impact of the availability of both DDGS are shown in Table 5.11. The diet is the same as in Table 5.10 (Corn DDGS included diet). This result confirms the higher economic value of corn DDGS in backgrounding diets relative to wheat DDGS.

Table 5.10 Beef Cattle Backgrounding Ration Results (Corn DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Barley	10.69	17.90	156.09	149.16	242.08
corn DDGS	13.09	21.87	163.79	-214.87	172.11
Limestone	0.64	1.08	105.00	-90.15	1880.88
Barley silage	53.75	90	32.90		34.83
grass hay	21.86	36.61	82.31	77.07	108.84
Totals	100	165.45	12.46		
			Total cost=$74.43		
Not selected	Cost	Value			
canola meal	206	174.09			
Wheat DDGS	1000	150.80			
Dical Phos	900	-426.80			

Table 5.11 Beef Cattle Ration Results (Wheat and Corn Distillers Grains)

Ingredient	Percent	Weight	Cost	Low	High
Barley	10.69	17.90	156.09	150.42	401.56
corn DDGS	13.09	21.87	163.79	-214.90	165.72
Limestone	0.64	1.08	105.00	-90.16	1042.59
Barley silage	53.75	90	32.90	0	34.83
grass hay	21.86	36.61	82.31	77.07	93.52
Totals	100	165.45	12.46		
			Total cost= $74.43		
Not selected	Cost	Value			
canola meal	206	174.09			
Wheat DDGS	153.13	150.80			
Dical Phos	900	-426.80			

5.6.4 Sensitivity Analysis: Changes in Substitute Feed Ingredient Price

A key factor that affects the demand and usage of a feed ingredient is the price of substitute feeds. Livestock producers usually substitute between feed ingredients in order to take advantage of price variations among feed ingredients. From the analysis in the preceding section, barley represents an important component of beef backgrounding diets. This section analyzes the impact of the changes in feed barley prices.

The least cost ration is examined under changes in the price of barley i.e. one standard deviation (35.73) in both directions. Table 5.12 shows the results of a decrease in barley price by one standard deviation. The price of barley used is approximately $120.36/tonne. With the reduction in the price of barley, diet cost reduces and the percentage of barley in the ration increases. With a cheaper energy source, energy is no longer limiting and hence wheat DDGS with its higher protein content replaces corn DDGS in the least cost ration.

Table 5.12 Beef Cattle Backgrounding Ration: Decrease in Barley Price

Ingredient	Percent	Weight	Cost	Low	High
Barley	22.67	38.01	120.36	113.26	148.66
wheat DDGS	3.54	5.94	153.13	123.74	173.24
Limestone	0.64	1.07	105	-13.03	1623.46
Barley silage	53.69	90	32.9		34.10
grass hay	19.45	32.60	82.31	79.09	86.65
Totals	100	167.62	11.24		
			Total Cost=$67.06		
Not selected	Cost	Value			
canola meal	206	169.52			
corn DDGS	163.53	149.73			
Dical Phos	900	52.82			

The cost of the optimal diet is considerably lower as a result of the lower price of barley. Table 5.13 examines the scenario of a one standard deviation increase in the price of barley. With the barley price at $191.82/tonne, energy becomes considerably more expensive. As a result, corn DDGS replaces wheat DDGS given its higher energy value.

Table 5.13 Beef Cattle Backgrounding Ration: Increase in the Price of Barley

Ingredient	Percent	Weight	Cost	Low	High
Barley	10.69	17.90	191.82	150.42	242.08
corn DDGS	13.06	21.87	163.79	-436.99	177.92
Limestone	0.64	1.08	105.00	-167.35	4000.42
Barley silage	53.75	90.00	32.90	0	36.49
grass hay	21.86	36.66	82.31	72.57	130.97
Totals	100	167.45	13.10		
			Total cost=$78.25		
Not selected	Cost	Value			
canola meal	153.13	136.08			
wheat DDGS	206	136.00			
Dical Phos	900	-2760.24			

5.6.5 Effect of Substitute Feed Prices on the Value of Distillers Grains

From the analysis in the preceding section, it seems that the competitiveness of the distillers co-product is largely dependent on its energy and protein value vis-a-vis other feed ingredients particularly barley and canola meal. To further explore these interactions a price matrix (Table 5.14) is constructed for the different price ranges of canola meal and barley.

The relative values of wheat and corn DDGS at the various prices are reported in the inner rows and columns. For clarity, the price of the latter is written in brackets. A feed ingredient is included in a least cost ration if its shadow value is equivalent or exceeds its market price value. The market price of wheat DDGS and corn DDGS used are $153.13 and $163.79 respectively. This implies that at a shadow value equivalent or exceeding these market values, the feed ingredient would be selected as a constituent of the least cost ration. In the present analysis, these inclusion shadow values are italicized and highlighted. The shadow value of a feed ingredient is affected by its nutrient composition, the nutrient requirement of the ration, the presence of other feed substitutes, etc. Maximum values for corn and wheat DDGS are reported for values that exceed the market value.

It can be deduced that wheat DDGS attains a higher value as canola meal price increases. This pattern is observed at low barley prices. The high protein content of the wheat DDGS ensures that it becomes valuable as its protein substitute in the diet becomes expensive. Considering that the 10-year average price of canola meal was $206/tonne, increased supplies of wheat DDGS in Western Canada could have a significant impact on the competitiveness of canola meal. Corn DDGS has a lower shadow value at lower price levels of barley (<$160/tonne).

Given the price of canola meal, as the price of feed barley increases, the value of corn DDGS increases and replaces wheat DDGS as price of the latter falls below its market value. The price matrix further confirms the higher economic value of corn DDGS relative to wheat DDGS in beef cattle backgrounding rations[28]. The price matrix also confirms the absence of complementarity between the by-products as none of the price combinations had both ingredients simultaneously reaching its market value.

The price analysis suggests interdependencies among values of the feed ingredients. This is a consequence of the high rate of substitutability among feed ingredients. Further, the present analysis indicates that the economic value of distillers by-product in a feed ration varies depending on the price and nutritional value of other nutrients. For example, although it might be generally economical to feed corn DDGS, during periods of low barley prices and higher canola meal prices, wheat DDGS may be of greater economic value. The analysis is repeated for the cattle finishing and hog diets in sections 5.7 and 5.8.

Further, various scenarios of price equivalence were assessed. This was to check the outcomes of the case of price parity between corn and wheat DDGS, barley and canola meal. To achieve this objective, the price of corn DDGS was separately set at $206/tonne (price of canola meal) and $156.09/tonne (price of barley). The substitute co-product ration Table 5.9 was the least cost ration in each case. The reverse was derived when the ration was re-run for wheat DDGS. The results confirm the observation that in the presence of a substitute distiller's co-product, if the price value of the other co-product exceeds its shadow value, the alternate formulation would represent the economically optimal ration.

[28] Indicated by the number of barley-canola meal combinations at which the value of corn exceeds wheat distillers grains.

Table 5.14 Effect of Substitute Feed Prices on the Value of Distillers Grains in Beef Backgrounding Diets

	Price of Canola Meal				
	140	160	180	200	220
Price of Feed Barley					
120	124.19 (129.32)	143.89 (143.10)	***163.60*** (149.56)	***173.49*** (149.56)	***173.49*** (149.56)
140	127.90 (139.33)	139.10 (148.88)	***155.78*** (159.07)	***159.88*** (159.07)	***159.88*** (159.07)
160	131.94 (149.50)	143.47 (159.05)	149.19 (***167.06***)	149.19 (***167.06***)	149.19 (***167.06***)
180	135.99 (159.68)	140.95 (***169.23***)	140.95 (***173.88***)	140.95 (***173.88***)	140.95 (***173.88***)
200	132.71 (169.86)	132.71 (***179.41***)	132.71 (***180.71***)	132.71 (***180.71***)	132.71 (***180.71***)
220	124.47 (***180.04***)	124.47 (***187.53***)	124.47 (***187.53***)	124.47 (***187.53***)	124.47 (***187.53***)
240	116.23 (***190.22***)	116.23 (***194.36***)	116.23 (***194.36***)	116.23 (***194.36***)	116.23 (***194.36***)
260	108.00 (***201.18***)	108.00 (***201.18***)	108.00 (***201.18***)	108.00 (***201.18***)	108.00 (***201.18***)

5.6.6 Influence of Market Factors

A number of market factors can affect the competitiveness of distiller's grains in feed rations. In this study the cost of transporting corn DDGS from the US to Western Canada was assumed to be CAN$50/tonne. Considering that the cost of transportation may change over time, this section examines the effect of changes in transportation cost on the competitiveness of corn DDGS and feed ration cost.

The cost of transportation is set at $60 per tonne to assess the impact of higher transportation cost. The equivalent price of corn DDGS is $173.79/tonne. The higher price of corn DDGS ensures that the co-product becomes less competitive and it is therefore priced out of the ration[29]. The wheat DDGS base diet (Table 5.9) becomes the optimal diet. Expectedly, at a lower transportation cost of $40/tonne, the price of corn DDGS reduces to $153.79/tonne and the optimal ration is that of Table 5.10 (Corn DDGS included diet).

This study further assesses the effect of variations in exchange rate on the competitiveness of the two types of distillers grains. Given the freight cost of $50/tonne and the domestic price of corn DDGS, the price of the by-product (delivered) i.e. $163.79 corresponds with a mean exchange rate of CAN$1.27/US$ (0.79 US$/CAN$). The corresponding least cost ration is reported in Table 5.15.

Table 5.15 Beef Cattle Ration Results at the Exchange of 0.79 US$/CAN$

Ingredient	Percent	Weight	Cost	Low	High
Barley	10.69	17.90	156.09	150.42	401.56
corn DDGS	13.09	21.87	163.79	-214.90	165.72
Limestone	0.64	1.08	105.00	-90.16	1042.59
Barley silage	53.75	90	32.90	0	34.83
grass hay	21.86	36.61	82.31	77.07	93.52
Totals	100	165.45	12.46		
			Total cost= $74.43		
Not selected	Cost	Value			
canola meal	206	174.09			
Wheat DDGS	153.13	150.80			
Dical Phos	900	-426.80			

[29] Given the price of corn DDGS and exchange rates, the switch to wheat DDGS occurs at a transportation cost of $53.39/tonne and higher.

As the Canadian dollar depreciates i.e. $0.79 to $ 0.76, the price of corn distillers grains increases from $163.79/tonne to $166.73/tonne. Priced at this level, corn DDGS becomes less competitive and is displaced from the diet by wheat DDGS. Table 5.16 reports the resultant least cost ration. It can be deduced that a weaker dollar seems to enhance the competitiveness of wheat DDGS and vice versa. This result confirms the patterns observed in the trade analysis section of this study (Section 5.2)

Table 5.16 Beef Cattle Ration Results at the Exchange of 0.76 US$/CAN$

Ingredient	Percent	Weight	Cost	Low	High
Barley	15.95	26.70	156.09	148.66	156.11
Wheat DDGS	10.06	16.83	153.13	11.71	153.14
Limestone	0.62	1.04	105.00	99.66	1495.59
Barley silage	53.77	90.00	32.90	0	34.60
grass hay	19.60	32.81	82.31	82.26	108.49
Totals	100	167.38	12.52		
			Total cost= $74.77		
Not selected	Cost	Value			
canola meal	206	183.69			
Corn DDGS	166.73	166.72			
Dical Phos	900	18.73			

5.6.7 Delimiting Protein

All the rations in the previous section were run with the crude protein content of the diet set at 15.50%. Discussions with livestock producers in Western Canada revealed that rations formulated without limits on protein are not uncommon. An assessment of such formulations is therefore a worthwhile exercise particularly considering that distillers grains are generally regarded as a less expensive protein source. The approach in this section is to re-run the various scenarios outlined in the previous analysis. The salient features of these rations are the compositions and cost of the various rations.

The base ration as shown by Table 5.17 contains significantly less barley and more grass hay than the results shown in Table 5.8. The composition of canola meal in the diet is slightly higher 3.59% as against 3.49% in the base ration of the previous section. Juxtaposing this against the wheat DDGS based diet (Table 5.18), it can be observed that wheat DDGS displaces both barley and canola meal from the diet. Cost of ration reduces from $76.63/tonne ($135.22/tonne DM basis) to $74.47/tonne ($124.16/tonne DM basis) - savings of $2.16/tonne ($11.06/tonne DM basis). From Tables B.6 and B.7 (Appendix B), the crude protein (21.7% vs. 13%) and phosphorous (0.507% vs. 0.367%) content of the diet is higher. This implies that although diet cost reduces, there may be possible negative environmental impacts from the overfeeding of nutrients particularly phosphorous. Diet cost reduces by $.30/tonne ($1.00/tonne DM basis) and $1.02/tonne ($2.37/tonne DM basis) relative to the restricted wheat DDGS and base rations respectively.

Table 5.17 Beef Cattle Backgrounding Ration Results (Base Ration)

Ingredient	Percent	Weight	Cost	Low	High
Barley	12.97	36.82	156.09	107.84	166.08
Canola meal	3.59	6.01	206	191.52	1043.35
Limestone	0.91	1.53	105	-97.36	850.77
Barley silage	53.70	90	32.90	0	34.87
grass hay	19.83	33.23	82.31	77.09	111.27
Totals	100	167.58	12.84		
			Cost=$76.63		
Not selected	Cost	Value			
wheat DDGS	1000	175.11			
corn DDGS	1000	182.09			
Dical Phos	900	15.95			

Results of the corn DDGS based ration are shown in Table 5.19. The distillers by-product completely replaces barley and canola meal similar to the case of wheat DDGS. Cost savings is approximately \$2.23/tonne (\$10.83/tonne DM basis[30]). Compared to Table 5.10, diet cost however increase by \$1.23/tonne on a DM basis. This suggests that when diets are formulated without restrictions on protein, wheat DDGS with its higher protein content has a higher economic value. This is because with no restriction on crude protein, distillers grains become a protein and energy supplement and more value is placed on the wheat DDGS because of its relatively higher crude protein. Expectedly, when both types of distillers grains are available, the model selects the wheat DDGS ration (Table 5.18) over corn DDGS.

Table 5.18 Beef Cattle Ration Results (Wheat DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Wheat DDGS	26.30	43.85	153.13	120.83	160.84
Limestone	0.90	1.50	105.00	-75.36	1663.32
Barley silage	53.98	90	32.90		34.50
grass hay	18.82	31.37	82.31	78.02	104.20
Totals	100	166.73	12.42		
			Total cost=\$74.47		
Not selected	Cost	Value			
Barley	156.09	148.66			
canola meal	206	180.74			
corn DDGS	1000	163.19			
Dical Phos	900	25.82			

[30] \$76.63/tonne (\$132.22/tonne DM) - \$74.40/tonne (\$124.39/tonne DM)

Table 5.19 Beef Cattle Rations Results (Corn DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Corn DDGS	22.67	37.89	163.79	125.81	172.11
Limestone	0.97	1.62	105.00	-75.42	1425.03
Barley silage	53.83	90	32.90		34.51
grass hay	22.53	37.67	82.31	78.02	106.94
Totals	100	167.19	12.44		
			Total cost=$74.40		
Not selected	Cost	Value			
Barley	156.09	149.16			
canola meal	206	181.47			
wheat DDGS	1000	153.65			
Dical Phos	900	25.28			

5.6.7.1 Changes in Substitute Prices

The analysis in this section is similar to the analysis of a decrease in feed barley prices. As reported by Table 5.20. At $120.36/tonne, barley re-enters the least cost ration and displaces most of the wheat DDGS in Table 5.17. Wheat DDGS remains largely as a supplementary protein source. Ration cost falls to $67.47/tonne ($113.07/tonne DM basis).

Table 5.20 Beef Backgrounding Ration Results (Reduction in Barley Price)

Ingredient	Percent	Weight	Cost	Low	High
Barley	23.39	39.20	120.36	113.26	148.66
wheat DDGS	3.64	6.10	153.13	123.74	173.24
Limestone	0.97	1.62	105	-13.03	1623.46
Barley silage	53.71	90.00	32.90		34.10
grass hay	18.29	30.65	82.31	79.09	86.65
Totals	100	167.57	11.31		
			Total Cost= $67.47		
Not selected	Cost	Value			
canola meal	206	169.52			
corn DDGS	163.79	149.73			
Dical Phos	900	52.82			

At a higher cost i.e. a standard deviation increment in the price of barley, the optimal ration reverts back to the wheat DDGS based ration (Table 5.11).

5.6.8 Market Factors: Changes in Transportation Cost

The influence of changes in transportation cost on the competitiveness of corn DDGS is reassessed. At a transportation cost of $60 per tonne, the corresponding price of corn DDGS is $173.79/tonne, the optimal ration is the wheat DDGS based diet (Table 5.11). At a lower transportation cost of $40/tonne, the resultant least cost ration is the corn DDGS based ration at a lower cost of $72.13/tonne.

5.6.9 Assessing the Economic Impact of Distillers Grains for a 5000 Head Cattle Backgrounding Operation.

This section of the study, extrapolates the implications of the cost analysis in the previous sections to a hypothetical 5000 cattle head backgrounding operation. This is to provide a broader context to the potential changes in feed cost that may occur with the inclusion of distillers grains. This analysis is done based on estimates of the least cost rations and the changes in costs attained with and without the utilization of wheat and corn distillers grains. The following parameters are used:

1. Weight range for backgrounding cattle: 500-850 lbs i.e. 350 lbs of gain
   Mean weight = 675 lbs
   175 day feeding program at 2 lbs/day

675×0.024% Body Dry Matter Intake (DMI) =16.2 lbs DMI/steer

16.2 lbs=7.36 kg DMI

Total Intake/steer for the entire feeding program: 175×7.36 =1288kg of feed total DM or 1.288 tonnes of DM

Cost of least cost ration (Base ration)[31] = $126.53/tonne DM

Cost per steer = 126.53×1.288=$162.97 cost/steer

For a 5000 herd of cattle = 5000 × cost per Head= 5000×162.97= $814,850.00

ii. Cost of least cost ration (inclusion of wheat DDGS) = $125.16
Cost per steer = $125.16 × 1.288 = $161.21 cost/steer

For a 5000 herd of cattle = 5000 × cost per Head = 5000×161.21 = $806,050.00

Cost savings with the use of wheat DDGS= $814,850.00-$806,050.00= **$8,800.00**

iii. Cost of least cost ration (inclusion of wheat DDGS) = $125.16

Cost per steer = $123.15 × 1.288 = $158.62 cost/steer

For a 5000 herd of cattle = 5000 × cost per Head = 5000×158.62 = $793,100.00

Cost savings with the use of corn DDGS = $814,850.00-$793,100.00 = **$21,750.00**

From the above analysis, the use of distillers grains has a positive impact on the feeding cost of the 5000 head backgrounding operation. Cost savings are however higher for the inclusion of corn distillers (i.e. $21750) as against that of wheat distillers grains (i.e. $8800). These estimates are sensitive to the number of days on feed, weight parameters, number of animals, and the rate of dry matter intake.

[31] For the conventional practice of a restricted protein diet formulation.

5.7 Cattle Finishing Ration

Rations for finishing beef cattle are high energy rations designed to put on gain as rapidly and efficiently as possible. This phase of beef production consists of full feeding of grain with limited amounts of roughage until market weight and finish are reached (The Merck Veterinary Manual 2008). The composition of grains in finishing usually exceeds 70%. Dupchak and Buchan (2008) noted that an animal on full feed would eat approximately 85% of its ration as grain and the remaining 15% as forage. McKinnon (2009) recommends a typical finishing ration can be formulated as illustrated in Table 5.21.

Table 5.21 Beef Cattle: Finishing Ration Specification

Nutrients	minimum level	maximum level
Crude Protein (%)	11.50	16.0
T.D.N (%)	78.00	
Calcium (%)	0.50	
Phosphorus	0.250	
Barley silage		90

Source: McKinnon (2009)

The analysis done for the beef backgrounding diets is repeated for the finishing rations. Table 5.22 shows the composition and cost of the base ration estimated under the scenario of distillers grains unavailability. Unlike the backgrounding diets, the finishing ration is predominately grain based with higher energy content. Given the price and percentage of barley grain in the diet, the cost of the ration is also higher than the backgrounding base ration. The cost of the finishing cattle base ration is approximately $122.60/tonne ($166.057/tonne DM basis).

With the introduction of wheat DDGS into the ration (i.e. Table 5.23), the cost of feed is reduced by $1.06/tonne ($1.26/tonne DM basis[32]) as part of the feed barley in the ration is replaced by the by-product. Juxtaposing this against the case of the backgrounding diet, it is obvious that the savings are lower in the finishing ration relative to the backgrounding diet. This is not unexpected considering the differences in grain composition of both rations.

Table 5.22 Finishing Cattle Base Ration Results

Ingredient	Percent	Weight	Cost	Low	High
Barley	72.34	97.98	156.09	114.85	164.40
Limestone	0.82	1.11	105	-110.26	759.65
Barley silage	26.85	36.36	32.90	22.70	34.70
Totals	100	135.45	16.16		
			Total Cost=$122.60		
Not selected	Cost	Value			
Wheat DDGS	1000	160.93			
Canola meal	206	193.68			
Corn DDGS	1000	173.02			
Grass hay	82.31	77.48			
Dical Phos	900	10.20			

[32] $166.057-$164.80/tonne DM basis

Table 5.23 Finishing Cattle Ration Results (Wheat DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Barley	59.81	81.09	156.09	148.58	205.37
Wheat DDGS	11.98	16.24	153.13	11.71	160.93
Limestone	0.78	1.05	105.00	-107.40	1424.78
Barley silage	27.44	37.20	32.90	15.28	34.60
Totals	100	135.59	16.48		
			Total Cost=$121.54		
Not selected	Cost	Value			
Canola meal	206	185.65			
Corn DDGS	1000	167.52			
Grass hay	82.31	77.73			
Dical Phos	900	11.58			

Reductions in feed ration cost is higher with the introduction of corn DDGS (Table 5.24)- approximately $7.29/tonne ($2.13/tonne DM basis) as the cost of diet reduces to $115.31/tonne ($163.93/tonne DM basis) from the base scenario of $166.06/tonne DM basis. It appears that the higher energy value of corn DDGS enables it to replace greater proportions of barley in finishing rations thereby reducing feed costs.

Table 5.24 Finishing Cattle Ration Results (Corn DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Barley	49.22	69.98	156.09	148.49	1304.81
Corn DDGS	16.21	23.04	163.79	67.85	173.02
Limestone	0.77	1.1	105	-105.04	1524.45
Barley silage	33.80	48.05	32.90	-22.30	34.55
Totals	100	142.17	16.39		
			Total Cost= $115.31		
Not selected	Cost	Value			
Wheat DDGS	1000	147.83			
Canola meal	206	180.20			
Dical Phos	900	12.52			
Grass hay	82.31	77.90			

In contrast to the wheat DDGS diet, the use of corn distillers grains reduces the cost of the diet by $.87/tonne DM basis. The optimal feed ration (same as Table 5.24) remains unchanged in the presence of both types of distiller's co-product.

5.7.1 Substitute Price Behaviour

A price matrix similar to that constructed for the backgrounding diet is repeated for the finishing rations (Table 5.25). The corresponding values of wheat DDGS and Corn DDGS are written in the inner rows with the latter in brackets. The matrix shows a common trend of rigidity in the value of wheat DDGS across several rows of price combinations. As a result of the higher energy requirements for finishing rations, the shadow value of wheat DDGS is low; ranging from $67.07 at low canola meal-high barley price combinations to $145.16 in high price canola- average price barley combinations. This notwithstanding, similar deductions of a higher protein value of wheat DDGS can be made[33].

Relative to backgrounding rations however, it seems that corn DDGS has a higher economic value in finishing rations as shown by the high values of the by-product at high price levels of canola meal and barley. Moreover, none of the price combinations yielded a shadow value for wheat DDGS that was equivalent to its market value. It can therefore be deduced that the availability of Corn DDGS has a greater impact on the competitiveness of wheat DDGS in beef cattle finisher diets relative to backgrounding diets.

[33] As shadow values generally tend to increase across rows and decrease along the columns.

Table 5.25 Effect of Changes in Substitute Feed Grain Prices on the Value of Distillers Grains in Beef Cattle Finishing Diets

	Price of Canola Meal				
	140	160	180	200	220
Price of feed Barley 120	123.24 (129.05)	123.41 (129.17)	123.41 (129.17)	123.41 (129.17)	123.41 (129.17)
140	115.22 (133.04)	134.66 (146.74)	144.21 (153.47)	144.21 (153.47)	144.21 (169.83)
160	107.20 (137.03)	126.63 (150.73)	145.16 (***164.43***)	145.16 (***169.41***)	145.16 (***169.41***)
180	99.17 (141.02)	118.61 (154.72)	131.47 (***168.42***)	131.47 (***179.05***)	131.47 (***179.05***)
200	91.15 (145.01)	110.58 (158.71)	117.79 (***172.41***)	117.79 (***186.11***)	117.79 (***188.70***)
220	83.12 (149.00)	102.56 (162.70)	104.10 (***176.40***)	104.10 (***190.10***)	104.10 (***198.34***)
240	75.10 (152.99)	90.42 (***166.69***)	90.42 (***180.39***)	90.42 (***194.09***)	90.42 (***207.79***)
260	67.07 (156.98)	76.73 (***170.68***)	76.73 (***184.38***)	76.73 (***198.08***)	76.73 (***211.78***)

5.7.2 Impact of Market Factors

The effect of higher transportation cost is assessed for the finishing diet. The objective is to examine whether a higher transportation cost affects the competiveness of corn DDGS in feed rations. At a higher transportation cost of $60 the wheat DDGS diet (i.e. Table 5.23) becomes the optimal diet[34]. The opposite (Table 5.24) pertains at a lower transportation cost.

The effect of variation in exchange rates is assessed for the finishing rations. At a corn DDGS price of $167.53/tonne, the by-product is substituted by wheat DDGS. The corresponding exchange rate is approximately 1.32CAN$/US$ (0.76US$/CAN$). Since this value is lower than the mean exchange rate i.e. 0.79US$/CAN$, the conclusion of a stronger dollar enhancing the competitiveness of corn DDGS can be made. Tables 5.26 and 5.27 report the least cost rations at exchange rates 0.79CAN$/US$ and 0.76CAN$/US$ respectively.

Table 5.26 Least Cost Ration at an Exchange Rate of 0.79 CAN$/US$

Ingredient	Percent	Weight	Cost	Low	High
Barley	49.22	69.98	156.09	148.49	1304.81
Corn DDGS	16.21	23.04	163.79	67.85	173.02
Limestone	0.77	1.1	105	-105.04	1524.45
Barley silage	33.80	48.05	32.90	-22.30	34.55
Totals	100	142.17	16.39		
			Total Cost= $115.31		
Not selected	Cost	Value			
Wheat DDGS	1000	147.83			
Canola meal	206	180.20			
Dical Phos	900	12.52			
Grass hay	82.31	77.90			

[34] Given the price of corn DDGS and exchange rates, the switch to wheat DDGS occurs at a transportation cost of $54.18/tonne

Table 5.27 Least Cost Ration at an Exchange Rate of 0.76 CAN$/US$

Ingredient	Percent	Weight	Cost	Low	High
Barley	59.81	81.09	156.09	148.58	156.11
Wheat DDGS	11.98	16.24	153.13	11.71	153.14
Limestone	0.78	1.05	105.00	101.13	1424.75
Barley silage	27.44	37.20	32.90	32.88	34.60
Totals	100	135.59	16.48		
			Total Cost= $121.54		
Not selected	Cost	Value			
Corn DDGS	167.53	167.52			
Canola meal	206.00	185.65			
Dical Phos	900	11.58			
Grass hay	82.31	77.73			

5.7.3 Assessing the Economic Impact of Distillers Grains for a 5000 Head Cattle Finishing Operation.

i. Weight range for finishing cattle: 850-1350 lbs i.e. 500 lbs of gain

Mean weight = 1100 lbs

152 day feeding program at 3.3lbs/day

1100×0.021% Body Dry Matter Intake (DMI) = 23.1 lbs DMI/steer

23.1 lbs = 10.5 kg DMI

Total Intake/steer for the entire feeding program: 152 × 10.5 = 1596 kg of feed total DM or 1.596 tonnes of DM

Cost of least cost ration (Base ration) = $166.057/tonne DM

Cost per steer = $166.057×1.596 = $265.03 cost/steer

For a 5000 herd of cattle = 5000 × cost per Head= 5000×265.03= $132, 5150.00

ii. Cost of least cost ration (inclusion of wheat DDGS) = $164.80

Cost per steer = \$164.80 × 1.596 = \$263.02 cost/steer

For a 5000 herd of cattle = 5000 × cost per Head = 5000×263.02 = \$1,315,100.00

Cost savings with the use of wheat DDGS= \$814,850.00-\$806,050.00 = **\$10,050.00**

iii. Cost of least cost ration (inclusion of wheat DDGS) = \$163.93

Cost per steer = \$163.93 × 1.596 = \$261.63 cost/steer

For a 5000 herd of cattle = 5000 × cost per Head = 5000×261.63 = \$1,308,150.00

Cost savings with the use of corn DDGS = \$814,850.00-\$793,100.00 = **\$17,000.00**

Following from the least cost rations, the use of distillers grains in finishing rations results in savings on feed cost. Similar to the conclusion derived from the backgrounding rations, corn distillers grains has a higher economic value in finishing rations relative to wheat. The magnitude of savings may change with variation in the number of days on feed, weight parameters, number of animals and the rate of dry matter intake.

5.8 Hog Rations

5.8.1 Introduction

Hogs are monogastric and unable to utilize fibre as effectively as ruminants. Key considerations in the diet of hogs is the concentration of amino acids particularly lysine and methionine. Traditionally, hog diets are corn-soybean based. In Western Canada however, wheat or barley usually substitutes for corn. This is due to the relative availability of wheat and barley vis -a-vis corn. High energy and protein feeds such as field peas are also used in feeding hogs in Western Canada (Hickling 2003). According to Racz (2010), a typical Western Canadian grower and finisher hog ration can be formulated as illustrated by Table 5.28. The grower hog requires higher amino acids, energy, vitamins and mineral levels than older finishing pigs (Tokach 2006). The percentage of distillers grain is restricted to 18% because of the limited ability of hogs to utilize high fibrous feed.

The analysis conducted in the previous section is repeated for hogs. Table 5.29 shows the hog grower base ration. As a result of the prohibitively high distillers grains price, the optimal least cost ration excludes the by-product from the diet. Feed wheat and field peas are the dominant feed ingredients used. Canola meal serves as a supplementary protein source, complementing the lower levels of methionine and cystine in peas (Hickling 2003). The availability of field peas ensures that the shadow value of soybean meal is lower than its market value. The total feed cost of the ration is $174.42/tonne.

Table 5.28 Hog Grower Diet Specification

Nutrients	minimum level	maximum level
Crude Protein (%)	16	18
DE Swine KC/KG	3150	
Calcium (%)	0.80	
Phosphorus (%)	0.650	
Lysine (%)	0.850	
Canola meal (%)		12.00
Corn DDGS (%)		18.00
Soybean meal		
Limestone (%)		3
Canola oil (%)		3
Wheat DDGS		18.00

Source: Racz (2010)

With the availability of wheat DDGS (Table 5.30), canola meal is displaced from the diet and the percentage of feed wheat significantly reduced. Barley enters the diet at a high percentage of 44 per cent. The composition of feed peas also increase to make-up for the lower protein (wheat DDGS relative to canola meal) and energy value of wheat DDGS. The energy content of the diet drops (Table E.1 Appendix E) although diet cost is reduced by $1.63/tonne. It can be observed that the economic value of wheat DDGS in the diet is dependent on the prices of other feeds such as field peas.

Table 5.29 Hog Grower Ration (Base Ration)

Ingredient	Percent	Weight	Cost	Low	High
Feed wheat	59.51	59.51	153.19	135.76	156.50
Canola meal	12.00	12	206	0	220.48
Peas	24.36	24.36	185.50	173.64	224.30
Limestone	3.00	3	105	0	128.66
Dical Phos.	1.13	1.13	900	511.69	2202.79
Totals	100	100	17.44		
			Total Cost=$174.42		
Not selected	Cost	Value			
barley	156.09	152.77			
wheat DDGS	1000	180.18			
Soybean meal	320.18	232.77			
Corn DDGS	1000	177.68			
Canola oil	783.29	128.66			

Table 5.31, shows the corn DDGS based diet, as a protein or energy feed, the co-product replaces most of the canola meal in the base ration and a proportion of feed wheat. The diet has higher energy content than the wheat DDGS based diet although energy is slightly lower than the base ration. Diet cost reduces to $173.56/tonne. It can therefore be deduced from the preceding analysis that feeding the co-product can reduce hog grower feeding cost by $0.86/tonne and $1.63/tonne for the corn DDGS and wheat DDGS based diets respectively. Although the wheat DDGs based diet has a relatively lower energy value.

Table 5.30 Hog Grower Ration (wheat DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Wheat	0.21	0.21	153.19	152.87	155.47
Barley	44.61	44.61	156.09	154.38	156.44
Wheat DDGS	17.89	17.89	153.13	122.39	155.69
Peas	33.07	33.07	185.50	177.76	188.80
Limestone	3.00	3.00	105	0	140.52
Dical Phos	1.22	1.22	900	755.28	1031.61
Totals	100	100	17.28		
			Total Cost=$172.79		
Not selected	Cost	Value			
Canola meal	206	202.42			
Soybean meal	320.18	208.40			
Corn DDGS	1000	160.45			
Canola oil	783.29	150.30			

Table 5.31 Hog Grower Ration (Corn DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Wheat	44.86	44.86	153.19	152.45	153.71
Canola meal	0.61	0.61	206.00	205.29	220.48
Peas	32.30	32.30	185.50	173.64	186.33
Corn DDGS	18.00	18.00	163.79	0	164.44
Limestone	3.00	3.00	105.00	0	141.74
Dical Phos	1.23	1.23	900.00	511.69	941.74
Totals	100	100	17.36		
			Total Cost=$173.56		
Not selected	Cost	Value			
Barley	156.09	155.06			
Soybean meal	320.18	213.92			
Wheat DDGS	1000	159.33			
Canola oil	783.29	150.30			

5.8.2 Effect of Substitute Prices

The price matrix constructed for cattle is repeated for hogs. In this section however, the resultant values of wheat DDGS and corn DDGS in response to changes in the prices of field peas and feed wheat prices are examined. This is because the two appear to be the dominant feeds in hog rations. In line with the earlier convention, the values of corn DDGS are written in brackets.

From Table 5.32 it can be observed that across rows the shadow value of wheat DDGS shows little variation, aside initial reductions in shadow values at low values of feed wheat. Similar trends can be observed across rows for corn DDGS. This is expected because the restrictions placed on the percentage of distillers grains in the diet make them a protein source. Feed wheat is primarily an energy source and hence changes in its price seem to have a limited effect on the value of distillers grains- especially when feed barley is also available.

The relatively high shadow value of wheat DDGS at average price values of field peas, indicate that the presence of field peas enhances the economic value of the by-product. However, as the price field peas continues to increase (price range $240-$260/tonne), the shadow value of wheat DDGS reduces from $132.22 to 89.01/tonne. This reduction in value may largely be a result of the availability of other protein feed substitutes such as soybean meal and canola meal that become economically valuable as field peas become increasingly expensive. Obviously the economic value of wheat DDGS in hog rations appears to be dependent on other feeds such as peas. Corn DDGS is generally less competitive in hog rations and come into the diet at high price levels of field peas (>$200/tonne) to provide supplemental protein and energy once field peas are priced out. Similar to the cattle diets, there is no evidence of complementarity.

Table 5.32 Effect of Changes in Substitute Feed Grain Prices on the Value of Distillers Grains in Hog Grower Rations

	Price of Feed Wheat			
	140	160	200	220
Pea Price				
120	94.69 (112.36)	82.50 (106.25)	82.50 (106.25)	82.50 (106.25)
140	150.38 (150.12)	129.22 (139.51)	129.22 (139.51)	129.22 (139.51)
160	***163.19*** (154.27)	***162.04*** (157.89)	***162.04*** (157.89)	***162.04*** (157.89)
180	***153.75*** (159.08)	***158.75*** (160.07)	***158.75*** (160.07)	***158.75*** (160.07)
200	***160.55*** (159.08)	***155.78*** (162.03)	***155.78*** (162.03)	***155.78*** (162.03)
220	***156.76*** (161.48)	152.46 (***164.24***)	152.46 (***164.24***)	152.46 (***164.24***)
240	132.22 (150.61)	149.14 ***(166.44***)	149.14 (***166.44***)	149.14 (***166.44***)
260	89.01 (125.59)	148.84 (***166.48***)	148.84 (***166.48***)	148.84 (***166.48***)

5.8.3 Hog Finisher Diets

Table 5.33 is a hog finisher diet specification. Not unlike, the grower diet, the amount of distillers co-product is restricted to values less than 20%. The energy content of the finishing ration is lower than that of the grower diet. The approach used in this section is similar to that used in previous sections.

Table 5.34 reports the results for the scenario of DDGS unavailability. Diet cost is $178.43/tonne. Barley comes into the base ration, whilst the composition of both feed wheat and peas reduces. With the introduction of wheat DDGS (Table 5.35) the cost of the base diet reduces by $1.77/tonne as canola meal is completely displaced and significant portions of barley in the diet are reduced. The crude protein content of the diet is higher than in the base ration, although the energy is slightly lower.

Table 5.33 Hog Finisher Diet Specification

Nutrients	minimum level	maximum level
Crude Protein (%)	15	
DE Swine KC/KG	3100	
Calcium (%)	0.850	
Phosphorus (%)	0.650	
Lysine (%)	0.70	0.90
Feed wheat		50
Wheat DDGS		18%
Corn DDGS		18%

Racz (2010)

Table 5.34 Hog Finisher Ration (Base)

Ingredient	Percent	Weight	Cost	Low	High
Wheat	50	50	153.19		156.30
Barley	21.09	21.09	156.09	153.13	178.82
Canola meal	4.45	4.45	206	203	239.12
Peas	20.82	20.82	185.50	171.87	187.17
Hog-min-vit	3.64	3.64	580	137.04	651.57
Totals	100	100	17.84		
			Total Cost=$178.43		
Not selected	Cost	Value			
Wheat DDGS	1000	171.35			
Soybean meal	320.18	228.16			
Corn DDGS	1000	167.42			

Table 5.35 Hog Finisher Ration (Wheat DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Wheat	50.00	50.00	153.19		155.88
Barley	7.97	7.97	156.09	153.40	185.12
Wheat DDGS	18.00	18.00	153.13		168.00
Peas	20.36	20.36	185.50	156.49	187.17
Hog-min-vit	3.67	3.67	580.00	146.29	651.57
Totals	100	100	17.57		
			Total Cost=$175.66		
Not selected	Cost	Value			
Corn DDGS	1000	165.20			
Canola meal	206	203.96			
Soybean meal	320.18	225.89			

The corn DDGS diet (Table 5.36) reduces the hog finisher based ration marginally i.e. $.34/tonne. Although the composition of the feed ration is similar to the wheat DDGS based diets, the higher cost of corn DDGS results in the difference in cost between the diets. The corn DDGs diet however has higher energy content. Expectedly, the protein content is lower.

Table 5.36 Hog Finisher Ration (Corn DDGS)

Ingredient	Percent	Weight	Cost	Low	High
Wheat	50.00	50.00	153.19		155.88
Barley	7.81	7.81	156.09	154.00	185.12
Peas	20.40	20.40	185.50	181.15	187.17
Corn DDGS	18.00	18.00	163.79		167.20
Hog-min-vit	3.79	3.79	580	146.29	651.57
Totals	100	100	17.81		
			Total Cost=$178.09		
Not selected	Cost	Value			
Wheat DDGS	1000	168			
Canola meal	206	203.96			
Soybean meal	320.18	225.89			

5.8.4 Co-Product Price Behaviour

The price matrix (Table 5.37) for the hog finisher shows a strong and stable value of wheat DDGS in most of the feed wheat- field pea price combinations. This may be as a result of the lower energy and lysine requirement of the finisher diet. Whilst corn DDGS has lower economic value (shadow value<market value) for low values of field pea, the value of wheat DDGS remains consistent often mostly exceeding its market value.

Table 5.37 Effect of Changes in Substitute Feed Grain Prices on the Value of Distillers Grains in Hog Finisher Diets

	Price of Feed wheat			
	140	160	200	220
Pea Price				
120	146.59 (143.94)	***176.61*** (148.26)	***176.61*** (148.26)	***176.61*** (148.26)
140	***153.13*** (150.13)	***173.33*** (150.43)	***173.33*** (150.43)	***173.33*** (150.43)
160	***159.66*** (156.92)	***159.66*** (156.92)	***159.66*** (156.92)	***159.66*** (156.92)
180	***166.20*** (163.42)	***166.20*** (163.42)	***166.20*** (163.42)	***166.20*** (163.42)
200	***166.61*** ***(165.75***)	***168.54*** (***165.75***)	***168.54*** (***165.75***)	***168.54*** (***165.75***)
220	***166.61*** ***(165.75)***	***168.54*** (***165.75***)	***168.54*** (***165.75***)	***168.54*** (***165.75***)
240	***166.61*** (***165.75***)	***168.54*** (***165.75***)	***168.54*** (***165.75***)	***168.54*** (***165.75***)
260	***166.61*** (***165.75***)	***168.54*** (***165.75***)	***168.54*** (***165.75***)	***168.54*** (***165.75***)

This result confirms the earlier results of the least cost rations which seems to suggest that the greatest economic value of wheat distillers grains appears to be in the hog finisher rations (cost savings approximating $1.80/tonne). Another attribute of the hog finishing price matrix is the high number of instances where the values of both kinds of distillers grains simultaneously exceed their market prices. This gives an indication of the possibility of complementarity in diets- both can be included in optimal diets[35].

This analysis is purely economic and does internalize the effect of feeding high quantities of the co-product on end-use characteristics such as carcass quality. Although the nutritional related literature reviewed does not seem to suggest any detrimental effects on product quality at the levels of DDGS used in the analysis.

Section 5.8.5 Economic Impact of Distillers Grains in Hog Rations

A typical hog feeding operation may involve the feeding of hogs with a starting weight of 20 kg to a finishing weight of approximately 100 kg. This involves feeding a grower diet from 20kg of weight to 65 kg of weight (45 kg of weight gain), and a finisher diet over a 35 kg weight gain range (i.e. 65 kg-100 kg). According to Racz (2010) about 153 kg of weight feed is required per grower hog to achieve this desired weight, whilst 126 kg weight of feed is necessary to achieve the desired finished weight. Hence the following deductions can be made:

(a). Weight of feed required for grower program/hog = 153 kg = 0.153 tonnes

Cost of base ration/tonne = $174.42/tonne

Cost of base ration/hog in tonnes = 0.153 × $174.42 = $26.69

Cost for a 5000 herd/tonne as fed = $26.69 ×5000 = $133,450.00

(b) Cost of wheat DDGS ration = $172.79/tonne

[35] According to Shurson (2008) as a result of the differences in the nutritional composition of wheat and corn DDGS, feeding these two sources may be complementary in swine diets.

Cost of wheat DDGS/hog in tonnes = 0.153 ×$172.79 = $26.44

Cost for a 5000 herd = $26.44 × 5000 = $132,200.00

Savings in feed cost = $133,450.00-$132,200.00 = **$1250.00**

(c) Cost of corn DDGS = $173.56/tonne

Cost of corn DDGS/hog in tonnes = 0.153 × $173.56 = $26.55

Cost for a 5000 herd = 5000 × $26.55 = $132750

Savings in feed cost = $133450-$132750 = **$700**

(b). Weight of feed required for finisher program/hog = 126 kg = 0.126 tonnes

Cost of base ration/tonne = $178.43/tonne

Cost of base ration/hog in tonnes = 0.126 × $178.43 = $22.48

Cost for a 5000 herd/tonne as fed = $22.48 ×5000 = $112400

(c) Cost of wheat DDGS ration = $175.66/tonne

Cost of wheat DDGS/hog in tonnes = 0.126 ×$175.66 = $22.13

Cost for a 5000 herd = $22.13 × 5000 = $110,650.00

Savings in feed cost = $112,400-$110,650 = **$1750.00**

(d) Cost of corn DDGS = $178.09/tonne

Cost of corn DDGS/hog in tonnes = 0.126 × $178.09 = $22.44

Cost for a 5000 herd = 5000 × \$22.44 = \$112,200.00

Savings in feed cost = \$112400-\$112200 = **\$200.00**

Chapter 6

Summary and Conclusions

6.0 Introduction

The surge in ethanol production in recent times has implications for different sectors: energy, food, etc. and has therefore seen a lot of research interest. The livestock industry remains in a complex position facing possible challenges on one hand in terms of higher feeding cost and potential opportunities, and on the other hand, in terms of the availability of relatively cheap, abundant by-products. For the livestock industry in Western Canada, proximity to the US presents additional opportunities, as the by-product could be imported to support the region's large livestock numbers in addition to domestic supply. Most of the present literature on the availability of distillers grains is primarily focused on nutrition. Considering that the inclusion or otherwise of a feed ingredient in a given ration is usually an economic decision, this study set out to examine the economic implications of distillers grains on the livestock industry in Western Canada. Combining macro and micro level approaches, the goal of this thesis was to (1) Estimate the potential market for distillers grains in Western Canada (2) Analyze the price relationships between traditional feed grains and distillers grains (3) Assess the impact of corn and wheat DDGS on feed cost in addition to the potential effects of other feed ingredients and market factors on the competitiveness of distillers grains.

6.1 Findings and Conclusions

The study found inter-alia that:

1. The potential supply of wheat DDGS in Western Canada is approximately 388,600 metric tonnes. The potential market demand is estimated to be in the region of 2 million metric tonnes, with the cattle industry making-up the largest market segment. From the trade data analysis the phenomenon of increasing US corn DDGS imports in Western Canada was observed suggesting the increasing importance of the US distillers grains market. In tandem with the results of the potential market estimation, Alberta's imports were the highest in Western Canada- a likely consequence of the large cattle population in the province.
2. The test for price interrelatedness showed positive long-run price relations between corn and wheat distillers grains and other traditional feed grains namely canola meal and barley. This indicates that deviations between the prices are only short term and that prices revert back to a long run equilibrium in which they trend in the same direction. The speed of adjustment coefficient suggested an indirect influence of the US corn market. The major implication of the price relationships observed is that overtime prices of corn and wheat distillers grains may be cheaper in relative but not absolute terms. In other words feeders may obtain economic benefits from feeding distillers grains albeit at a higher cost trajectory.
3. From the feed cost analysis of the beef cattle and hog sectors wheat and corn distillers grains generally have a positive effect on diets, reducing feeding cost, with cost savings ranging from $7.29 to $0.34/tonne of diet (on as fed basis). From the beef backgrounding ration analysis, corn DDGS tend to have higher economic value than wheat DDGS reducing feed cost by $1.06/tonne as against $0.72/tonne of diet (on as fed basis) by the latter. Overfeeding protein only resulted in marginal reductions in feeding costs. Considering the excess protein

and phosphorus fed and the implications for nutrient management. This practice appears not to be economically prudent.

4. Despite the high proportion of grains in the rations and the ability of distillers grains to displace portions of these grains, the inclusion of distillers grains in beef cattle finishing rations tended to have similar economic impacts as the backgrounding rations. Whilst the two kinds of distillers grains had a positive economic impact on feed ration cost, corn DDGS has the highest economic value in finishing rations reducing feed cost by $7.29/tonne of diet (on as fed basis). The competitiveness of distillers grains in beef cattle rations is affected by the prices of barley and canola meal and market factors such as freight costs and exchange rates.
5. Similar conclusions of reductions in feed cost can be deduced for hog rations, although wheat DDGS tended to have a higher economic value in hog rations, reducing feed cost by $1.63 and $1.77/tonne of diet (on as fed basis), in hog grower and finishing rations respectively. The inclusion of corn DDGS on the other hand reduced hog grower and finisher diets by $0.86 and $0.34/tonne of diet (on as fed basis) respectively. The diverse impacts of the two types of distillers grains are noticeable from this analysis. Producers of wheat DDGS may find it economically beneficial to target high-protein dependent livestock sectors, whilst corn DDGS appears more suitable for high energy diets. Similar to the beef cattle sector the behaviour of substitute prices especially the price of field peas, impacts on the economic value of distillers grains. This study also found the potential for the complementary use of both kinds of distillers grains in hog diets.

It can therefore be concluded that distillers grains could have a positive impact on the economics of livestock feeding in Western Canada. This is however dependent on a number of factors such as the price of substitute feed ingredients, exchange rates and transportation costs. Further, although corn DDGS generally tended to have a higher economic value, the impact of the ethanol by-product tends to be diverse across the different livestock rations.

6.2 Limitations of Study and Suggestions for Future Research

A major limitation of this thesis was the unavailability of adequate price data on wheat DDGS. Aside from the industry in Western Canada being relatively young, most of the ethanol producers contacted were unwilling to provide such data. As a result of this, approximation techniques were used to derive the price of wheat DDGS. This may affect the validity of some of the conclusions made from the time-series analysis especially regarding the interrelatedness between wheat DDGS and barley and canola meal prices. The effect of approximation pricing on the least cost ration results may not be as significant.

Secondly, the present study does not incorporate nutrient management costs. It indirectly isolates feed costs from other costs incurred as a result of certain feeding practices. Future studies can incorporate these costs to ascertain how conclusions may differ. An incorporation of nutrient management costs in addition to improving the price data for key feed ingredients such as wheat DDGS in future studies would provide a better understanding of the economic value of distillers grains. Furthermore, future research could consider the effect of nutrient variability on the conclusions of the present study.

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APPENDIX A

WESTERN CANADA LIVESTOCK NUMBERS

Table A.1 Cattle ('000 Head)

Year	Alberta	British Columbia	Manitoba	Saskatchewan	Western Canada	Canada
1999	6056	800	1400	2719	10975	14753.4
2000	6279	805	1400	2750	11234	14968.4
2001	6500	815	1425	2900	11640	15424.5
2002	6387	836.5	1470	2940	11633.5	15420.9
2003	6100	885	1590	3220	11795	15670
2004	6400	950	1730	3540	12620	16610
2005	6700	915	1735	3625	12975	16880
2006	6300	820	1680	3450	12250	16000
2007	6410	805	1540	3430	12185	15825
2008	6010	750	1515	3385	11660	15195

Source: Statistics Canada 2009

Table A.2 Hogs ('000 Head)

Year	Alberta	British Columbia	Manitoba	Saskatchewan	Western Canada	Canada
1999	1807.9	147.8	1916.8	917.8	4790.3	12392.4
2000	1918.2	167.9	2295.5	1028.4	5410	13401
2001	2029.4	168.3	2556	1129.1	5882.8	14050.4
2002	2140.9	168	2785	1230.4	6324.3	14715
2003	2030	160	2850	1250	6290	14720
2004	2030	155	2890	1350	6425	14980
2005	2000	144	2940	1395	6479	15195
2006	2056	135	2980	1389	6560	15065
2007	1970	129	2965	1320	6384	14690
2008	1670	120	2720	971	5481	12980

Source: Statistics Canada 2009

APPENDIX B

NUTRIENT COMPOSITION: BACKGROUNDING RATIONS

Table B.1 Nutrient Composition of Base Ration

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	13.00	15.50
T.D.N	%	66.50	66.50	69.50
Dry matter	%		100	
Calcium	%	0.60	0.60	0.80
Phosphorus	%	0.25	0.37	0.40
Crude Fibre	%		19.72	
Crude Fat	%		3.03	

Table B.2 Nutrient Composition (Inclusion of Wheat DDGS)

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	15.50	15.50
T.D.N	%	66.50	66.50	69.50
Dry matter	%		100	
Calcium	%	0.600	0.600	0.800
Phosphorus	%	0.250	0.395	0.400
Crude Fibre	%		19.956	
Crude Fat	%		2.935	

Table B.3 Nutrient Composition (Inclusion of Corn DDGS)

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	15.146	15.50
T.D.N	%	66.50	66.50	69.50
Dry matter	%		100	
Calcium	%	0.600	0.600	0.800
Phosphorus	%	0.250	0.400	0.400
Crude Fibre	%		18.692	
Crude Fat	%		1.874	

Table B.4 Nutrient Composition: Price of Barley Reduced by One Standard Deviation

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	13	15.50
T.D.N	%	66.50	66.5	69.50
Dry matter	%		100	
Calcium	%	0.600	0.6	0.800
Phosphorus	%	0.250	0.349	0.400
Crude Fibre	%		19.380	
Crude Fat	%		2.547	

Table B.5 Nutrient Composition: Price of Barley Increased by One Standard Deviation

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	15.146	15.50
T.D.N	%	66.50	66.50	69.50
Dry matter	%		100	
Calcium	%	0.600	0.600	0.800
Phosphorus	%	0.250	0.400	0.400
Crude Fibre	%		18.692	
Crude Fat	%		1.874	

Rations without Limits on Protein

Table B.6 Nutrient Composition (Base ration)

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	13.00	
T.D.N	%	66.50	66.50	69.50
Dry matter	%		100	
Calcium	%	0.800	0.800	
Phosphorus	%		0.368	
Crude Fibre	%		19.305	
Crude Fat	%		3.038	

Table B.7 Nutrient Composition (Inclusion wheat DDGS)

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	21.668	
T.D.N	%	66.50	66.500	69.50
Dry matter	%		100.00	
Calcium	%	0.800	0.800	
Phosphorus	%		0.507	
Crude Fibre	%		20.952	
Crude Fat	%		3.883	

Table B.8 Nutrient Composition (Inclusion of Corn DDGS)

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	17.682	
T.D.N	%	66.50	66.500	69.50
Dry matter	%		100	
Calcium	%	0.800	0.800	
Phosphorus	%		0.455	
Crude Fibre	%		17.985	
Crude Fat	%		1.522	

Table B.9 Nutrient Composition (Decrease in Barley price=$CAN 120.36)

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	17.682	
T.D.N	%	66.50	66.500	69.50
Dry matter	%		100	
Calcium	%	0.800	0.800	
Phosphorus	%		0.455	
Crude Fibre	%		17.985	
Crude Fat	%		1.522	

Table B.10 Price of Wheat DDGS Equivalent to Barley/ Corn DDGS is Unavailable

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	21.668	
T.D.N	%	66.50	66.500	69.50
Dry matter	%		100	
Calcium	%	0.800	0.80	
Phosphorus	%		0.507	
Crude Fibre	%		20.952	
Crude Fat	%		3.883	

Table B.11 Price of Corn DDGS Equivalent to Barley /Wheat DDGS is unavailable

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	17.682	
T.D.N	%	66.50	66.500	69.50
Dry matter	%		100	
Calcium	%	0.800	0.800	
Phosphorus	%		0.455	
Crude Fibre	%		17.985	
Crude Fat	%		1.522	

Table B.12 Price of Canola Equivalent to Wheat DDGS /Corn DDGS is Unavailable

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	13.00	13.00	
T.D.N	%	66.50	66.50	69.50
Dry matter	%		100	
Calcium	%	0.800	0.80	
Phosphorus	%		0.368	
Crude Fibre	%		19.305	
Crude Fat	%		3.038	

APPENDIX C

NUTRIENT COMPOSITION: FINISHER RATIONS

Table C.1 Base Ration Finishing Diets

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	11.50	12.269	16.00
T.D.N	%	78	78	80.00
Dry matter	%	100	100	
Calcium	%	0.5	0.50	
Phosphorus	%	0.250	0.369	
Crude Fibre	%		8.698	
Crude Fat	%		2.338	
Salt	%			

Table C.2 Wheat DDGS Availability

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	11.50	16.00	16.00
T.D.N	%	78	78	80.00
Dry matter	%		100	
Calcium	%	0.500	0.50	
Phosphorus	%	0.250	0.437	
Crude Fibre	%		9.551	
Crude Fat	%		2.915	
Salt	%			

Table C.3 Corn DDGS Availability

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	11.50	16	16.00
T.D.N	%	78	78	80.00
Dry matter	%		100	
Calcium	%	0.500	0.500	
Phosphorus	%	0.250	0.448	
Crude Fibre	%		8.221	
Crude Fat	%		1.840	
Salt	%			

Table C.4 Price of Barley Equivalent to Wheat DDGS/Corn DDGS Unavailable

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	11.50	16	16.00
T.D.N	%	78	78	80.00
Dry matter	%		100	
Calcium	%	0.400	0.40	0.550
Phosphorus	%	0.250	0.437	
Crude Fibre	%		9.743	
Crude Fat	%		2.916	
Salt	%			

Table C.5 Price of Barley Equivalent to Corn DDGS/Unavailable Wheat DDGS

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	11.50	16.0	16.00
T.D.N	%	78	78.00	80.00
Dry matter	%		100	
Calcium	%	0.400	0.400	0.550
Phosphorus	%	0.250	0.448	
Crude Fibre	%		8.423	
Crude Fat	%		1.847	
Salt	%			

Table C.6 Barley Price at $191.82/tonne

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	11.50	16	16.00
T.D.N	%	78	78	80.00
Dry matter	%		100	
Calcium	%	0.400	0.400	0.550
Phosphorus	%	0.250	0.437	
Crude Fibre	%		9.743	
Crude Fat	%		2.916	
Salt	%			

Table C.7 Corn DDGS Price at 173.79

NUTRIENTS	UNITS	MIN	ACTUAL	MAX
Weight	KG	100	100	100
Crude Protein	%	11.50	16	16.00
T.D.N	%	78	78	80.00
Dry matter	%		100	
Calcium	%	0.400	0.400	0.550
Phosphorus	%	0.250	0.437	
Crude Fibre	%		9.743	
Crude Fat	%		2.916	
Salt	%			

APPENDIX E

NUTRIENT COMPOSITION: HOG RATIONS

Table E.1 Nutrient Composition of Grower ration

Nutrient Composition	Base Ration	Wheat DDGS Availability	Corn DDGS availability	Price Equivalence
Weight	100	100	100	100
CR. Protein (%)	17.349	18.00	18.00	18
DE Swine KC/KG	3347.061	3150.006	3267.207	3263.728
ME Poultry KC/KG	2706.063	2464.353	2242.151	2241.158
Dry matter(%)	88.529	88.653	88.528	88.525
Calcium(%)	1.479	1.451	1.428	1.428
Phosphorus(%)	0.650	0.650	0.650	0.650
Available Phos.(%)	0353	0.353	0.366	0.367
Crude Fibre(%)	3.787	6.157	2.989	3.010
Crude fat(%)	3.117	2.457	1.378	0.850
Lysine(%)	0.850	0.850	0.850	0.610
Meth+Cyst.(%)	0.609	0.544	0.613	0.178
Tryptophan(%)	0.200	0.173	0.719	0.634
Theonine(%)	0.623	0.619	0.635	0.182
Methionine(%)	0.273	0.235	0.184	0.911
Arginine(%)	1.076	1.143	0.908	0.569
Dig. Lys SW(%)	0.687	0.813	0.566	0.152
Dig. Met SW(%)	0.229	0.131	0.155	0.316

Table E.2 Nutrient Composition of Hog Finisher Rations

Nutrient Composition	Base Ration	Wheat DDGS Availability	Corn DDGS availability	Price Equivalence
Weight	100	100	100	100
CR. Protein (%)	15	18.058	16.839	20.333
DE Swine KC/KG	3270.777	3235.731	3241.232	3210.747
ME Poultry KC/KG	2766.250	2653.440	2299.114	2148.058
Dry matter(%)	88.235	88.507	88.371	88.727
Calcium(%)	0.850	0.850	0.850	0.850
Phosphorus(%)	0.691	0.735	0.734	0.798
Available Phos.(%)	0.432	0.449	0.459	0.473
Crude Fibre(%)	3.939	4.748	2.852	3.879
Crude fat(%)	2.279	2.399	1.370	2.068
Salt(%)	0.255	0.257	0.265	0.700

Lysine(%)	0.700	0.700	0.700	0.724
Meth+Cyst.(%)	0.510	0.602	0.598	0.177
Tryptophan(%)	0.178	0.176	0.172	0.610
Theonine(%)	0.521	0.553	0.561	0.218
Methionine(%)	0.226	0.255	0.173	0.862
Arginine(%)	0.911	1.041	0.747	0.582
Dig. Lys SW(%)	0.548	0.693	0.435	0.114
Dig. Met SW(%)	0.189	0.145	0.145	0.252