# Biodiesel Benefits for Cattle Producers:

## Feeding Byproducts of Biodiesel Production

Greg Lardy, Ph.D.

Western Organization of Resource Councils

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Prepared for the Western Organization of Resource Councils

# WORC

WORC, the Western Organization of Resource Councils, is a regional network of seven grassroots community organizations that include 10,000 members and 44 local chapters. WORC helps its member groups succeed by providing training and coordinating regional issue campaigns.

WORC's mission is to advance the vision of a democratic, sustainable, and just society through community action. WORC is committed to building sustainable environmental and economic communities that balance economic growth with the health of people and stewardship of their land, water, and air resources.

WORC's member groups are: Dakota Resource Council (North Dakota), Dakota Rural Action (South Dakota), Idaho Rural Council, Northern Plains Resource Council (Montana), Oregon Rural Action, Powder River Basin Resource Council (Wyoming), and Western Colorado Congress.

# The Report

*Feeding Byproducts of Biodiesel Production* was written and compiled by Greg Lardy, Ph.D. Dr. Lardy is Associate Professor of Animal Sciences at North Dakota State University.

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An online version of this guide is available for download at *www.worc.org*.


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# Contents

# Executive Summary

The biodiesel industry in the United States is entering a period of rapid growth. Increases in the cost of diesel fuel are also increasing the interest in renewable fuels in the agricultural community. When oilseeds are used to produce biodiesel, a large amount of byproduct is produced. Oilseed meals are useful protein supplements for beef cattle and can be used in a wide variety of beef cattle diets. In the region which WORC serves (Colorado, Idaho, Montana, Oregon, North Dakota, South Dakota and Wyoming), the most common use will likely be as a protein supplement for cows grazing dormant pastures during the fall and winter months. It is relatively easy to integrate the use of these byproducts into beef cattle operations, particularly in the northern Great Plains, where many beef cows graze dormant native range or other low quality forages for much of the fall and winter.

The purpose of this paper is to review the nutritive value of various oilseeds used in biodiesel production in the region served by the Western Organization of Resource Councils and to give feeding recommendations for the resulting oilseed meals. In addition, this paper briefly reviews the physical and chemical processes used to produce biodiesel from oilseed crops.

Major oilseed crops in the region which could potentially be used for biodiesel production include soybeans, sunflowers, safflower, mustard, camelina, and canola. Of these, camelina, sunflower, and canola have the greatest oil content.

During the biodiesel production process, oilseeds are crushed and oil expelled. In some cases the remaining cake or meal may be sold at that point, while in others, it may undergo solvent extraction to remove the additional residual oil. The oil undergoes a process known as transesterification in which the triglyceride is converted to glycerol and three methyl esters. The oilseed meals which remain following the oil extraction process are valuable livestock feeds. Soybean meal is the highest quality vegetable oil meal due primarily to its favorable amino acid content and high digestibility. It is used widely in monogastric (swine and poultry) diets across the world. Other oilseed meals generally have lower digestibilities and/or less favorable amino acid profiles when compared to soybean meal. However, the meals from other oilseeds are still very useful, especially in diets for ruminant animals where amino acid profile and fiber level are not as problematic as in monogastric diets.

In beef cattle applications, the most common use of oilseed meals is as a protein supplement, either in beef cow diets or in growing and finishing diets for feedlot cattle. Little research has been conducted with glycerol and its use as a feed ingredient and therefore it is difficult to make broad recommendations regarding its use in livestock diets. Increased interest in renewable fuels, specifically biodiesel, will lead to a greater availability of byproducts which result from biodiesel production. These feed ingredients are suitable for use in a wide variety of beef cattle diets.

Oilseed meals can be used as a feedstuff in a wide variety of beef cattle nutrition applications. However, they are best suited for use as protein supplements in wintering diets for beef cows or in growing and finishing diets for beef calves. With this in mind, it is relatively easy to integrate the use of these byproducts into beef cattle operations, particularly in the northern Great Plains, where many beef cows graze dormant native range or other low quality forages for much of the fall and winter. In these situations, supplementation using feedstuffs such as grain milling coproducts (wheat middlings, distillers grains), commercial supplements, or oilseed meals is quite common during the fall and winter.

Byproducts resulting from either on-farm or small scale production of biodiesel would be quite useful to ranchers in this region.

# Introduction

Biodiesel production is expanding rapidly throughout the United States (Figure 1; National Biodiesel Board, 2007). Biodiesel is produced from a number of vegetable oils, animal fats, as well as waste fats and oils. The expansion in the biodiesel industry has occurred primarily because of increasing interest in renewable fuels and reducing dependence on foreign oil sources in the United States. Many different oilseeds and animal fats are used in commercial production of biodiesel, including soybean, canola, sunflower, and tallow. Other crops such as camelina show promise as potential sources of biodiesel.

In order to make biodiesel, the oil must be removed from the oilseed. In commercial processes, this occurs through the use of a combination of mechanical (pressing) and chemical (hexane) extraction. Following oil extraction, the remaining meal can be used for livestock feed. Many farm scale biodiesel producers utilize mechanical means to remove the oil from the oilseed but do not employ chemical extraction processes. This results in meals which have slightly different nutrient composition than processes which employ both processes in tandem.

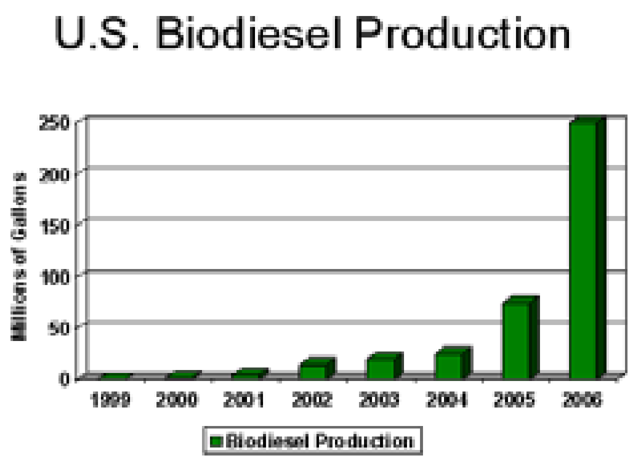


**Figure 1. Annual biodiesel production in the United States. National Biodiesel Board, 2007.**

Biodiesel is produced by a process known as transesterification. In this process, mono-alkyl esters of long chain fatty acids are produced from vegetable oils or animal fats. This process requires the addition of methanol and a catalyst such as sodium hydroxide or potassium hydroxide.

The purpose of this paper is to explain the production methods used to produce biodiesel, the nutritive value of the resulting byproducts, and to give feeding recommendations for the various oilseed meals that result from the production of biodiesel.

# Oilseed Production

The WORC region includes the states of North and South Dakota, Montana, and parts of Idaho, Colorado, and Oregon. This region varies greatly in its agriculture practices and in the types of crops and livestock produced. For the purposes of this paper, focus will be drawn to the major oilseed crops which are grown in this region. These crops include soybeans, canola, sunflower, safflower, camelina, and mustard. Of these, soybeans, canola, and sunflower are by far the most important, both in terms of acreage and in terms of economic importance to rural communities (Table 1). Soybeans are grown primarily in North and South Dakota. The two states each grew over 3.8 million acres of soybeans in 2006. Canola is grown primarily in North Dakota (940,000 acres in 2005) with much smaller amounts grown in Montana and Idaho. Sunflower is also an important crop in North Dakota, South Dakota, and Colorado. Safflower and mustard are grown in Montana and South Dakota and are grown in much smaller quantities than canola or sunflower. However, on individual farming or ranching operations, these oilseed crops may play an important role in small scale biodiesel production.

Camelina is a crop which shows promise as a potential oilseed for biodiesel production. Very little commercial production exists at the present time, but research is underway in Montana to evaluate its agronomic characteristics as well as its usefulness as a livestock feed following biodiesel production.

**Table 1. Oilseed acreage in the WORC region in 2006.**

| | Canola | Mustard | Safflower | Sunflower | Soybean |
|---|---|---|---|---|---|
| Colorado | NA | NA | NA | 100,000 | NA |
| Idaho[1] | 19,500 | NA | NA | NA | NA |
| Montana[2] | 10,000 | 11,500 | 29,000 | 6,800 | NA |
| North Dakota | 940,000 | NA | NA | 900,000 | 3,870,000 |
| Oregon | NA | NA | NA | NA | NA |
| South Dakota | NA | 40,500 | 16,500 | 530,000 | 3,850,000 |
| Wyoming | NA | NA | NA | NA | NA |

[1] Idaho canola data are reported for 2005 (the latest year for which statistics are available).

[2] Montana sunflower and mustard data reported for 2005 (the latest year for which statistics are available).

Oilseed production statistics follow the trend in acreage (Table 2). Soybeans, canola, and sunflower are by far the most important oilseed crops in the region. In the WORC region, soybean production is dominated by North and South Dakota which produced over 7 billion pounds of soybeans each in 2006. Production of sunflowers and canola is dominated primarily by North Dakota, which leads the nation in production of both sunflower (1,115 million pounds) and canola (1,281 million pounds). Sunflower production is also important in South Dakota and Colorado. Mustard and safflower production are much lower relative to the production of soybeans, canola, or sunflower.

**Table 2. Oilseed production in the WORC region in 2006 (million pounds).**

| | Canola | Mustard | Safflower | Sunflower | Soybeans |
|---|---|---|---|---|---|
| Colorado | NA | NA | NA | 108.6 | NA |
| Idaho[1] | 31.2 | NA | NA | NA | NA |
| Montana[2] | 10.9 | 0.6 | 27.75 | 7.4 | NA |
| North Dakota | 1,281.00 | NA | NA | 1,115.00 | 7,198.20 |
| Oregon | NA | NA | NA | NA | NA |
| South Dakota | NA | 28.2 | 5.4 | 437.6 | 7,854.00 |
| Wyoming | NA | NA | NA | NA | NA |

[1]Idaho canola data are reported for 2005 (the latest year for which statistics are available).

[2]Montana sunflower and mustard data reported for 2005 (the latest year for which statistics are available).

**Beef Cow Numbers.** The region represented by WORC is an important cow-calf production area in the United States. Much of the land mass in the region is native grasslands in arid and semi-arid portions of the intermountain west and northern Great Plains. This region has been and will continue to be a very important cow-calf production area. Of the states in the WORC region, South Dakota has the most beef cows (1.669 million; Table 3). Montana, North Dakota, Wyoming, and Colorado also have large numbers of beef cows. Over the last 10 years, much of this region has been severely impacted by drought. This has reduced beef cow numbers markedly in some states, particularly Montana, Wyoming, and Colorado. As the region recovers from this drought, it is likely that beef cow numbers will increase somewhat as ranches are restocked and moisture levels return to normal. This region is recognized as a leader in cow-calf production and calves from the Northern Great Plains are recognized as some of the highest quality feeder calves in the nation.

**Table 3. Beef cow numbers in the WORC region in 2007.**

| State | Beef cow inventory |
|---|---|
| Colorado | 725,000 |
| Idaho | 472,000 |
| Montana | 1,382,000 |
| North Dakota | 939,000 |
| Oregon | 575,000 |
| South Dakota | 1,669,000 |
| Wyoming | 763,000 |

**Ability to React and Adapt.** Those involved in production agriculture in the WORC region have always had the ability to successfully adapt to changes in order to survive and prosper. The advent of increased interest in renewable fuels will likely be no different than other opportunities and challenges faced by producers in the past. When given opportunities to successfully compete, the region's farmers can quickly adapt to the production of new crops, new production and growing methods, and new market opportunities. As technology for producing biodiesel improves, the region's farmers and ranchers will have the ability to change to meet the needs of new markets and new economic alternatives.

# Nutrient Composition of Oilseeds Prior to Processing

All oilseeds vary in nutrient composition. The values discussed in this paper reflect previously published data or data collected from various sources and may not be reflective of individual lots of oilseeds on any given operation. A laboratory analysis should be conducted on each lot to determine the actual crude protein and fat content.

## Camelina

**Nutrient Content.** Camelina seed contains approximately 38% oil and 27% crude protein on a dry matter basis. Very little research has been conducted to evaluate the energy value and other feeding characteristics of camelina. The crop is sometimes referred to as 'false flax' or 'gold-of-pleasure' since, like flax, the oil contains relatively high proportions of C18:3 (omega 3) fatty acid (see Table 4).

**Anti-nutritional Factors.** Camelina contains glucosinolates. The levels of these compounds in camelina varieties tested in Europe are relatively low (18.6 micromoles per gram) compared to other crops such as crambe or mustard (115 and 130 micromoles per gram, respectively; Matthäus and Angelini, 2005). Camelina also contains relatively low amounts of other anti-nutritional factors such as sinapine and condensed tannins.

Research conducted at North Dakota State University indicates that feeding flax seed, which is also high in C18:3, to beef cattle increases the amount of 18:3 present in the resulting meat products (Maddock et al., 2006). With increased interest in the health aspects of 18:3 fatty acids in human diets, additional research with camelina which investigates this as a potential marketing alternative may be warranted.

Unfortunately, due to its novelty, camelina is not recognized by the Food and Drug Administration (FDA) as a Generally Regarded As Safe (GRAS) feed ingredient. Until this recognition is granted, it is unlawful to use camelina and camelina meal as an ingredient in livestock rations. Work is currently underway in Montana to gain this approval. More information about the approval is available at the following links:

*http://agr.mt.gov/camelina/* *http://agr.mt.gov/camelina/issuesdraft6_12-28-07.pdf*

## Canola

**Nutrient Content.** Canola seed contains approximately 40.5% fat and 21% crude protein, making it one of the higher fat oilseeds available for biodiesel production. As a result of its high fat content, its estimated energy value is also quite high. Compared to soybeans, canola has higher levels of fat and lower levels of crude protein.

**Anti-nutritional Factors.** Canola was originally bred from industrial rapeseed and both are members of the *Brassica* family of plants. In the breeding process the amounts of glucosinolates were lowered and the fatty acid profile of the oil was also changed substantially. The reduction in the amount of glucosinolates present in the seed and in the resulting meal (compared to rapeseed) is a definite benefit from a livestock feeding perspective. High levels of glucosinolates can result in impaired thyroid function, reduced feed intakes, and reduced weight gains. The levels of glucosinolates found in canola do not present a problem in livestock feeding operations. Palatability also can be affected negatively by high levels of glucosinolates.

**Table 4. Nutrient composition of various oilseeds.**
**Dry matter basis**

| | DM, % | CP, % | Fat, % | TDN, % | NEm, Mcal/lb | NEg, Mcal/lb | ADF, % | Ca, % | P, % |
|---|---|---|---|---|---|---|---|---|---|
| Camelina | 88.7 | 27 | 37.8 | 110.2 | 1.27 | 0.91 | 15.1 | NR | NR |
| Canola | 92 | 21 | 40.5 | 115 | 1.34 | 0.97 | 12 | 0.35 | 0.68 |
| Mustard | 94.2 | 35.1 | 34.4 | 69 | 0.69 | 0.42 | 27 | 0.33 | 1.04 |
| Safflower | 93 | 17.5 | 32 | 91.2 | 1 | 0.65 | 40 | 0.26 | 0.67 |
| Sunflower | 94.9 | 17.9 | 41.9 | 121 | 1.42 | 1.03 | 39 | 0.18 | 0.56 |
| Soybeans | 91 | 41.7 | 19.2 | 91 | 0.96 | 0.67 | 10 | 0.27 | 0.63 |

Abbreviations: DM = Dry Matter; TDN = Total Digestible Nutrients; NEm = Net Energy for Maintenance; NEg = Net Energy for Gain; CP = Crude Protein; ADF = Acid Detergent Fiber; Ca = Calcium; P = Phosphorus; NR = Not reported.

## Mustard

**Nutrient Content.** Mustard is not typically used for livestock feed. However, it does contain relatively high levels of fat (34.4%) and crude protein (35.1%).

**Anti-nutritional Factors.** Mustard is also a member of the *Brassica* family and does contain glucosinolates. In fact, glucosinolates are what imparts the mustard flavor to mustard. As with the glucosinolates in canola, a number of metabolic functions related to thyroid metabolism may be affected by glucosinolates.

## Safflower

**Nutrient Content.** Safflower seed contains 17.5% crude protein and 32% fat and can be used as a protein and energy supplement for beef cattle and sheep. Safflower seed is high in oil and therefore high in energy. However, the safflower hull is relatively indigestible. Research conducted in Montana indicates that feeding high linoleic whole safflower seed may improve survival of calves subjected to cold stress (Lammoglia et al., 1999). In North Dakota research, feeding ewes supplemental safflower prior to lambing improved lamb survival (Encinias et al., 2004).

**Anti-nutritional Factors.** Safflower seed contains no known anti-nutritional factors which would pose a problem in livestock production.

## Sunflower

**Nutrient Content.** Oil-type sunflower seeds are high in fat (42%) and protein (18%). Whole sunflower seeds may be included as a protein and energy supplement. Because of their high fat content, whole seeds should be limited to 10 to 15 percent of the ration. Whole sunflower seeds do not need to be processed before feeding. Some producers raise confection sunflowers under contract for various food companies. In general, confection sunflower varieties are lower in fat than oil-type varieties, and as a consequence, are lower in energy.

**Anti-nutritional Factors.** Sunflower seeds contain no known anti-nutritional factors which would pose a problem in livestock production.

## Soybeans

**Nutrient Content.** Soybeans contain 42% crude protein and 19% fat and are the most widely produced oilseed crop in the United States. Whole soybeans can be fed to many different classes of livestock as both a protein and energy source. Unlike sunflowers and safflower, the hull of the soybean is relatively high in energy since it is high in digestible fiber. The amino acid profile of soy protein is excellent and soy protein is the preferred protein source in most swine and poultry diets in the United States.

**Anti-nutritional Factors.** Soybeans contain trypsin inhibitors which can interfere with digestion, especially in monogastrics. In ruminants, this is generally not a problem. Roasting or other processing methods which involve heating or toasting will generally inactivate the trypsin inhibitors.

# The Biodiesel Production Process

When oilseeds are used in the production of biodiesel, the process for oil extraction is similar to other oilseed crushing operations where the goal is to remove the oil for either industrial or food grade applications (Figure 2). In commercial applications, a combination of mechanical and chemical extraction processes are typically used. In smaller, farm-scale operations, mechanical means alone are generally the most common method.

## Steps in the Biodiesel Production Process

**Cleaning.** The oilseed may be cleaned first to remove any soil, rocks, chaff, or other foreign material prior to crushing. This typically improves efficiency and reduces the chance of expensive repairs if the crushing equipment were damaged by foreign objects.

**Pressing or Mechanical Extraction.** The oilseed is crushed in a mechanical press which physically squeezes the oil from the meal. Depending on the capabilities of the crushing equipment utilized in the process, relatively high levels of residual oil may remain in the meal.

**Solvent or Chemical Extraction.** In commercial operations, the press extracted meal typically undergoes chemical or hexane extraction which removes the majority of the residual oil from the meal. This step is not generally part of small scale or on farm production of biodiesel.

**Transesterification.** Once crude vegetable oil has been obtained through physical and/or chemical means, the oil then undergoes a process known as transesterification (Figure 3). In this process, the raw vegetable oil

**Figure 2. Biodiesel Production Process**

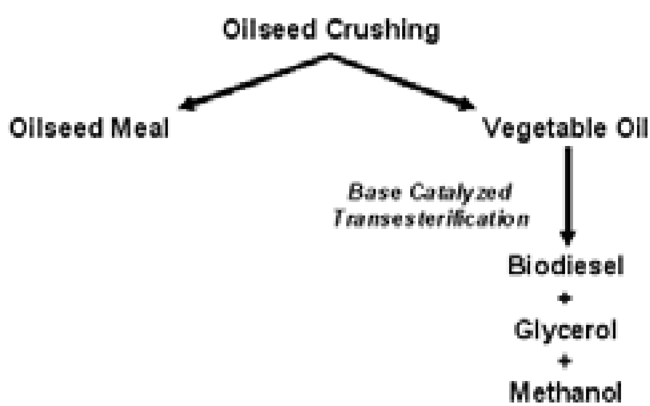


Figure 2. General diagram of the biodiesel production process.

is combined with methanol and a catalyst (typically potassium hydroxide). This converts the triglycerides in the vegetable oil to glycerol and three methyl ester groups.

**Refining.** Once the raw biodiesel has been obtained, it is typically refined to remove impurities. In addition the glycerol which is obtained in the biodiesel production process is also refined if it is to be used in other applications. Methanol is also recovered and is recycled for use in the process at a later date.

**Solvent extraction versus expeller extraction.** The major difference between commercial biodiesel production and on-farm or small scale biodiesel production is that commercial operations typically use solvent extraction to remove residual oil from the oilseed meal prior to the time the raw vegetable oil undergoes transesterification. Solvent extraction generally results in a meal which is very low in residual oil (1 to 2%). Depending on the efficiency of the mechanical extraction process, residual oil levels can vary from 10 to 15% oil in the oilseed meal with mechanical extraction alone. There are some obvious disadvantages related to these efficiencies. Since the oil is typically a more valuable component of the oilseed, leaving large amounts of residual oil in the meal results in reduced operating efficiency and increased cost of production. From a livestock feeding standpoint, the increased oil content of the meal is certainly a positive which can result in improved nutritional and energy content of the meal. These items must be considered when exploring the potential for small scale biodiesel production.

## Figure 3. Production Process

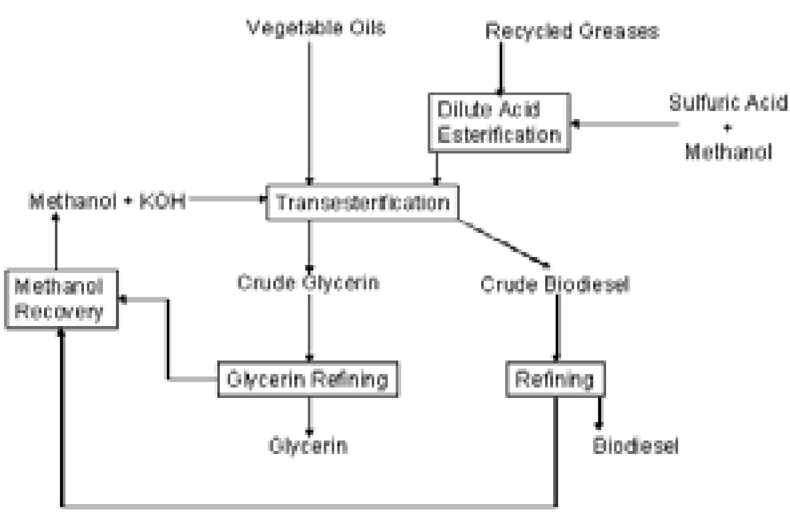


**Figure 3. Detailed schematic of the biodiesel production process (adapted from Kerr et al., 2007).**

**Expected Oil Yields and Projected Biodiesel Production.** Expected oil yields per ton of oilseed and projected amounts of biodiesel per ton of oilseed are presented in Table 5. Due to the high oil content of sunflower, camelina, and canola, the yields of biodiesel per ton of seed are greater for these oilseed crops than for other oilseeds such as soybeans.

**Table 5. Projected oil yields and biodiesel yields from various oilseeds.**

| Oilseed | Fat Content, % | Pounds of Oil per Ton | Pounds of Biodiesel[1] | Gallons of Biodiesel[2] |
|---|---|---|---|---|
| Camelina | 40.4 | 808 | 808 | 110.7 |
| Canola | 40.5 | 810 | 810 | 111 |
| Mustard | 34.4 | 688 | 688 | 94.2 |
| Safflower | 32 | 640 | 640 | 87.7 |
| Sunflower | 41.9 | 838 | 838 | 114.8 |
| Soybeans | 19.2 | 384 | 384 | 52.6 |

[1]Assuming all oil is extracted from the meal. 100 pounds of oil plus 10 pounds of methanol yields 100 pounds of biodiesel and 10 pounds of crude glycerol.

[2]Assuming 7.3 pounds per gallon

# Resulting Byproducts

**Camelina Meal.** Camelina meal results from the oil extraction of camelina. Little data has been collected to determine its feeding value. The mechanically extracted meal contains approximately 13% fat and about 41% crude protein, making it similar to other oilseed meals in terms of general nutrient quality.

Since the quantities of glucosinolates and other antinutritional factors are relatively low in camelina seed, one would expect the levels to be relatively low in the resulting meal as well. German research (Böhme, and Flachowsky, 2005) indicates camelina meal is better suited for ruminants such as sheep and cattle than it is for swine and poultry due to the presence of antinutritional factors, lower digestibility, and/or a relatively poor amino acid profile (see Table 6).

Unfortunately, due to its novelty, camelina is not recognized by the Food and Drug Administration (FDA) as a Generally Regarded As Safe (GRAS) feed ingredient. Until this recognition is granted, it is unlawful to use camelina and camelina meal as an ingredient in livestock rations. Work is currently underway in Montana to gain this approval. More information about the approval is available at the following links:

*http://agr.mt.gov/camelina/*  *http://agr.mt.gov/camelina/issuesdraft6_12-28-07.pdf*

**Canola Meal.** Canola meal is a coproduct protein meal remaining after edible oil is extracted from canola. The meal contains 40 to 44 percent crude protein and makes a good source of supplemental protein for cattle fed low-protein forages or cows grazing dormant range. Expeller canola meal may contain up to 8 percent oil compared to 0.5 percent in solvent extracted meal, providing added energy from residual oil.

Canola does contain compounds called glucosinolates. At high levels, glucosinolates can interfere with thyroid metabolism. However, canola has been selected for low levels of glucosinolates and the levels of glucosinolates in canola meal do not pose a problem or hazard for livestock which are fed canola meal as a source of supplemental protein.

## Table 6. Nutrient composition of various oilseed meals resulting from solvent or mechanical extraction.

### Dry matter basis

| | DM, % | CP, % | Fat, % | TDN,% | NEm, Mcal/lb | NEg, Mcal/lb | ADF,% | Ca,% | P,% |
|---|---|---|---|---|---|---|---|---|---|
| Camelina meal, mechanical extraction | 91.5 | 36.5 | 14.1 | 88.6 | 0.97 | 0.64 | 19.2 | 0.38 | 0.77 |
| Canola meal, mechanical extraction | 90 | 41 | 7.4 | 76 | 0.8 | 0.52 | 16 | 0.6 | 0.94 |
| Canola meal, mechanical extraction, On-farm press | 92.6 | 36.9 | 14.1 | 88 | 1.09 | 0.77 | NG | 0.6 | 1.02 |
| Canola meal, solvent extraction | 90 | 43.6 | 1.2 | 69 | 0.73 | 0.45 | 18 | 0.67 | 1 |
| Mustard meal, mechanical extraction | 93 | 34.5 | 5.5 | 73 | 0.76 | 0.48 | NG | NG | NG |
| Safflower meal, mechanical extraction | 91.9 | 23.5 | 7.2 | 56.1 | 0.55 | 0.25 | NG | 0.26 | 0.66 |
| Safflower meal, solvent extraction | 92 | 25.4 | 1.1 | 57 | 0.55 | 0.29 | 41 | 0.37 | 0.81 |
| Soybean meal, mechanical extraction | 90.7 | 46.7 | 5.2 | 84.9 | 0.94 | 0.62 | NG | 0.31 | 0.65 |
| Soybean meal, solvent extraction | 89 | 49 | 1.2 | 84 | 0.94 | 0.64 | NG | 0.33 | 0.71 |
| Sunflower meal, mechanical extraction, On-farm press | 93.1 | 23.6 | 19 | 90.5 | 1.13 | 0.8 | NG | 0.43 | 0.79 |
| Sunflower meal, solvent extraction | 90 | 38.9 | 1 | 64 | 0.65 | 0.35 | 28 | 0.39 | 1.06 |

Abbreviations: DM = Dry Matter; TDN = Total Digestible Nutrients; NEm = Net Energy for Maintenance; NEg = Net Energy for Gain; CP = Crude Protein; ADF = Acid Detergent Fiber; Ca = Calcium; P = Phosphorus; NG = Not Given.

Nutrient content of oilseeds and oilseed meals vary. Producers should have samples analyzed by a laboratory to ensure the most accurate data for each particular feed.

Canola meal can be used in a wide variety of beef cattle diets including as a protein supplement for beef cows or as an ingredient in rations for growing and finishing cattle.

Canola meal is widely used in Canada as a source of protein for swine and poultry diets as well. It has a favorable amino acid profile and is commonly used as a protein supplement for barley based rations (see Table 6).

**Mustard Meal.** Little data exists on the feeding value of mustard meal in livestock rations. In most cases, mustard is not raised for the purposes of oil production for industrial uses, but rather for use in condiments and other flavoring applications. Consequently, the value of the seed is generally great enough that applications for animal feeding are generally not economical. However, given the high concentrations of glucosinuolates in the mustard seed, one would expect even higher concentrations in the meal. This would likely result in lower levels of animal performance in monogastric diets (see Table 6).

**Safflower Meal.** Safflower meal can be used as a protein supplement for low protein forages or in backgrounding diets where a source of natural protein is needed. Safflower meal is relatively low in energy (57 percent total digestible nutrients) due to the inclusion of the hulls with the meal. Safflower meal can be used in a wide variety of beef cattle diets, however, its relatively low nutrient content will limit its usefulness in many applications. It is probably best suited for use as a protein supplement for beef cows fed lower protein diets. Because of its low energy content, safflower meal is not utilized by swine and poultry producers (see Table 6).

**Soybean Meal.** Soybean meal is the gold standard to which all other oilseed meals are compared. It is highly digestible, is low in fiber, and has an excellent amino acid profile. This makes it particularly appealing for use in the swine and poultry industries. As a result, it is typically not priced competitively with other oilseed meals as a source of supplemental protein for beef cattle producers. However, its nutrient profile makes it well suited for use in any beef cattle diets as a source of supplemental protein when it is priced competitively (see Table 6).

**Sunflower Meal.** Sunflower meal is another coproduct protein meal which remains following oil extraction from sunflowers. The meal contains 32 to 35 percent crude protein and can be used effectively as a protein supplement in beef cattle rations. Lower (28 percent crude protein) or higher (40 percent or more crude protein) protein levels are the result of adding or removing sunflower hulls from the meal product. Sunflower hulls are relatively indigestible and addition of hulls to the meal lowers the energy content of the meal as well, so a nutrient analysis of the meal is appropriate. In addition, there is considerable variation from plant to plant with the amount of hull added back to the meal, which contributes to increased variation in the nutrient content of the meal.

Sunflower meal can be used as a protein supplement for beef cows fed low protein diets and as an ingredient in growing and finishing diets for beef calves. Its amino acid profile, fiber level, and lower digestibility make it less desirable for monogastric animals such as swine and poultry (see Table 6).

## Glycerol

Glycerol is a byproduct of the conversion of triglycerides to methyl esters in the transesterification process. Approximately 10% of the weight of the oil or fat going into the process will end up as crude glycerol as a byproduct at the completion of the reaction. Consequently, finding a use for this byproduct has important implications for the economics of most biodiesel production facilities.

Limited research has been conducted to investigate the usefulness of glycerol as a feedstuff. However, what has been conducted so far indicates that glycerol can be included as a component of many different types of diets. Research has been conducted with dairy cows and sheep. Research with beef cattle is currently underway at several institutions around the country. Research conducted with feeding glycerol indicates it has an energy value similar to corn on a pound for pound basis in dairy cows.

**Table 7. Analysis of glycerol.**

| | |
|---|---|
| **Moisture, %** | 9.22 |
| **Dry matter basis, %** | |
| **Crude Glycerol** | 95.8 |
| **Methanol** | 0.03 |
| **Crude protein** | 0.45 |
| **Crude fat** | 0.13 |
| **Ash** | 3.51 |
| **Sodium** | 1.39 |
| **Chloride** | 2.05 |
| **Potassium** | < 0.005 |

**Source: Iowa State University, 2007.**

Glycerol is also known as glycerin or glycerine. It is a colorless, odorless, sweet tasting liquid. One of the concerns regarding glycerol feeding is the fact that small amounts of methanol can remain with the glycerol after refining. Methanol is toxic to livestock. Table 7 details the laboratory analysis of glycerol. Glycerol contains very small amounts of crude protein and crude fat. Sodium and chloride are the two minerals which make up the majority of the ash content.

# Hypothetical Examples

## What do these numbers mean on a typical operation?

### Camelina

- 300 cow ranch.
- Feeding protein supplement to cows on winter range from December through February.
- Assume 2 pounds of protein supplement (oilseed meal) per head per day.
- Total protein supplement required = 300 x 90 days x 2 pounds per head per day = 54,000 pounds or 27 tons of oilseed meal.
- Assume an average yield of 1552 pounds of camelina per acre and 37.8% fat and 62.2% meal. Each acre would yield 965 pounds of meal (1552 x 62.2%).
- To support the protein supplement needs for the 300 cow ranch, 56 acres of camelina would be required (27 T/0.48 Tons of meal per acre).

### Soybeans

- 300 cow ranch.
- Feeding protein supplement to cows on winter range from December through February.
- Assume 2 pounds of protein supplement (oilseed meal) per head per day.
- Total protein supplement required = 300 x 90 days x 2 pounds per head per day = 54,000 pounds or 27 tons of oilseed meal.
- Assume an average yield of 1950 pounds of soybeans per acre and 19.2% fat and 81.8% meal. Each acre would yield 1595 pounds of meal (1950 x 81.8%).
- To support the protein supplement needs for the 300 cow ranch, 34 acres of soybeans would be required (27 T/0.8 Tons of meal per acre).

## Canola

- 300 cow ranch.
- Feeding protein supplement to cows on winter range from December through February.
- Assume 2 pounds of protein supplement (oilseed meal) per head per day.
- Total protein supplement required = 300 x 90 days x 2 pounds per head per day = 54,000 pounds or 27 tons of oilseed meal.
- Assume an average yield of 1363 pounds of canola per acre and 40.5% fat and 59.5% meal. Each acre would yield 811 pounds of meal (1363 x 59.5%).
- To support the protein supplement needs for the 300 cow ranch, 66.5 acres of canola would be required (27 T/0.406 Tons of meal per acre).

## Sunflower

- 300 cow ranch.
- Feeding protein supplement to cows on winter range from December through February.
- Assume 2 pounds of protein supplement (oilseed meal) per head per day.
- Total protein supplement required = 300 x 90 days x 2 pounds per head per day = 54,000 pounds or 27 tons of oilseed meal.
- Assume an average yield of 1340 pounds of sunflowers per acre and 41.9% fat and 58.1% meal. Each acre would yield 779 pounds of meal (1340 x 58.1%).
- To support the protein supplement needs for the 300 cow ranch, 69 acres of sunflowers would be required (27 T/0.39 Tons of meal per acre).

**Table 8. Projected oilseed yields and biodiesel yields from various oilseeds (per acre basis).**

| Crop | Yield/Acre lbs | Oil /Acre, lbs | Pounds of Biodiesel/ Acre | Gallons of Biodiesel/Acre |
|---|---|---|---|---|
| Cameilina | 1200 | 485 | 485 | 66.4 |
| Canola | 1362 | 552 | 552 | 75.6 |
| Mustard | 700 | 241 | 241 | 33 |
| Safflower | 957 | 306 | 306 | 42 |
| Sunflower | 1240 | 520 | 520 | 71.2 |
| Soybeans | 1860 | 357 | 357 | 48.9 |

[1]Assuming all oil is extracted from the meal. 100 pounds of oil plus 10 pounds of methanol yields 100 pounds of biodiesel and 10 pounds of crude glycerol.
[2]Assuming 7.3 pounds per gallon

# Opportunities to Integrate Byproducts into Cattle Operations

**Suitability for grass/forage based systems.** With the exception of glycerol, the byproducts mentioned above all fall into the general class of feedstuffs commonly referred to as oilseed meals. Oilseed meals can be used as a feedstuff in a wide variety of beef cattle nutrition applications. However, they are best suited for use as protein supplements in wintering diets for beef cows or in growing and finishing diets for beef calves. With this in mind, it is relatively easy to integrate the use of these byproducts into beef cattle operations, particularly in the northern Great Plains, where many beef cows graze dormant native range or other low quality forages for much of the fall and winter. In these situations, supplementation using feedstuffs such as grain milling coproducts (wheat middlings, distillers grains), commercial supplements, or oilseed meals is quite common during this time period.

Byproducts resulting from either on-farm or small scale production of biodiesel would be quite useful to ranchers in this region. One potential challenge for processing plants or farmers with on-farm biodiesel production units which would need to be investigated further is the seasonality of demand for the byproduct. The bulk of the material would be utilized during the fall and winter months, with little supplementation taking place in the spring and summer. As a consequence, additional storage may be needed in order to keep the oilseed meal produced at times when demand and usage are lower. However, this is certainly not an insurmountable problem.

Glycerol is a unique byproduct with little known about its characteristics and how it might be utilized in grass or forage based systems of beef cattle production. It may have applications as an ingredient in liquid supplements or as an ingredient in beef cattle rations. However, additional research may be needed to discover the optimum manner to utilize this byproduct in a cost effective manner.

# Conclusions and Recommendations

The biodiesel industry in the United States is entering a period of rapid growth. Increases in the cost of diesel fuel are also increasing the interest in renewable fuels in the agricultural community. When oilseeds are used to produce biodiesel, a large amount of byproduct is produced. Oilseed meals are useful protein supplements for beef cattle and can be used in a wide variety of beef cattle diets. In the region which WORC serves, the most common use will likely be as a protein supplement for cows grazing dormant pastures during the fall and winter months. It is relatively easy to integrate the use of these byproducts into beef cattle operations, particularly in the northern Great Plains, where many beef cows graze dormant native range or other low quality forages for much of the fall and winter. Ranchers should work with their local extension professionals or nutritionists do determine the optimum and most cost effective supplementation strategy.

Limited research work has been conducted with glycerol and additional research is required before conclusive recommendations and feeding strategies can be developed. Availability of byproducts that result from biodiesel production will likely continue to increase as interest in biodiesel continues to increase. Therefore livestock producers in the WORC region should be poised to utilize these byproducts in their operations.

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The biodiesel industry in the United States is entering a period of rapid growth. Increases in the cost of diesel fuel are also increasing the interest in renewable fuels in the agricultural community. When oilseeds are used to produce biodiesel, a large amount of byproduct is produced. Oilseed meals are useful protein supplements for beef cattle and can be used in a wide variety of beef cattle diets. In the region which WORC serves (Colorado, Idaho, Montana, Oregon, North Dakota, South Dakota and Wyoming), the most common use will likely be as a protein supplement for cows grazing dormant pastures during the fall and winter months. It is relatively easy to integrate the use of these byproducts into beef cattle operations, particularly in the northern Great Plains, where many beef cows graze dormant native range or other low quality forages for much of the fall and winter.

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