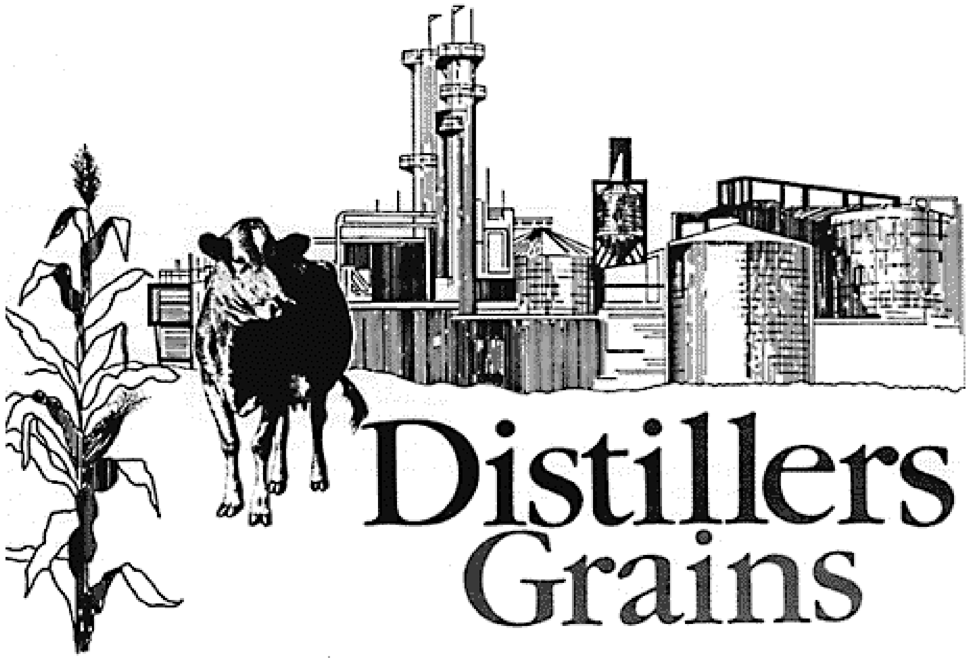
MP51 Distillers Grains

Glen Aines
Universitiy of Nebraska - Lincoln

Terry Klopfenstein
Universitiy of Nebraska-Lincoln, tklopfenstein1@unl.edu

Rick Stock
Universitiy of Nebraska - Lincoln, rstock3@Unl.edu

MP51, 1986



Glen Aines, Terry Klopfenstein and Rick Stock

Summary

In the conventional production of alcohol from grain for fuel, byproducts are produced with excellent feeding value for ruminants. Appropriate use of these byproducts aids the efficient production of animals and enhances the economics of alcohol production.

In the fermentation of corn to produce alcohol, the starch in the corn is converted to alcohol and carbon dioxide. The nutrients in the corn other than starch are concentrated about three times because corn is about two-thirds starch. Even though starch is high in energy, the one-third of the corn remaining in the byproduct after fermentation contains as much energy per pound as did the corn from which it was

produced. Two-thirds of the total weight of the corn is lost but the **concentration** of energy in corn and distillers byproducts is similar. This energy is mainly in the form of protein, fiber and fat.

Two byproducts are produced: distillers grains and thin stillage. Characteristics of the nutrients in the two byproducts are quite different and often confuse the discussion of distillers byproducts. After fermentation of the corn by yeast to produce alcohol and then distillation to recover the alcohol, the remaining material is called whole stillage. In most cases, whole stillage, which is usually 90 percent water, is screened or centrifuged to produce distillers grains and thin stillage. The distillers grains contain primarily unfermented corn residues (protein, fiber, fat). The thin stillage contains yeast cells, soluble nutrients and very small corn particles. Thin stillage is often called distillers solubles. However, this is a misnomer, because much of the material is not really soluble, but is instead a suspension of fine particles.

Compared to screening, centrifuging tends to put more of the fine particles in the distillers grains fraction and less in the thin stillage. Fineness of grind of the corn feedstock also affects these relative proportions. On the average, one-third of the byproduct is thin stillage and two-thirds distillers grains, but this ratio can vary depending upon processing equipment and conditions. Typical analyses of distillers grains and thin stillage are shown in *Table I*.

In most large distilleries, the distillers grains are dried (DDG) and the thin stillage is concentrated to a molasses-like consistency. The thin stillage may be marketed as such, or may be dried on the DDG to produce distillers grains plus solubles (DDGS).

Table I. Nutrient composition of distillers byproducts compared to corn and soybean meal (dry basis).

		Corn distillers			
	Corn Grain	**Dried Grains**	**Solubles[a]**	**Dried gains + solubles**	**Soybean meal, 44%**
Protein %	10	29.5	29.8	29.6	48
Fiber %	2.2	12.8	4.2	9.0	5.9
Fat %	3.5	8.0	9.0	8.4	1.3
Calcium %	.02	.10	.30	.15	.3
Phosphorus%	.26	.70	1.40	.78	.7
TDN %	87	87	87	87	82
NE_{milk} (Mcal/lb)	.91	.91	.91	.91	.88
NE_{gain} (Mcal/lb)	.65	.65	.65	.65	.61
$NE_{maintenance}$ (Mcal/lb)	.95	.95	.95	.95	.91
Lysine, % of protein	2.5	2.9	4.2	3.3	6.5

[a]Also referred to as thin stillage.

Beef Cattle

Distillers byproducts are valuable sources of protein and energy. During the past few years, we have realized that the primary value of a protein source for ruminants is its bypass value. Bypass protein is the protein that escapes (or bypasses) digestion in the rumen. This protein is subsequently digested in the intestinal tract. Protein degraded in the rumen to ammonia is of similar value as urea. Soybean meal (SBM) is the most common protein for ruminants; however, only 25-30 percent of SBM protein is bypassed. Recent research suggests that the bypass value for DDG is at least 200 percent and DDGS is 160 percent that of SBM. Thin stillage is more degradable than the DDG and therefore DDGS has less bypass protein than DDG. These bypass values were determined with intestinally-fistulated animals and also with animal growth trials.

There is considerable disagreement among nutritionists as to the value of DDG and DDGS. Much of this is due to the assumptions made in the design and interpretation of growth studies. Unless certain criteria are met, such as demonstrating that protein is limiting, the relative values obtained are misleading.

Based on the bypass values previously discussed, an appropriate mixture of DDG or DDGS and urea would be equal in feeding value to SBM. Usually the DDG(S) mixture costs less than SBM. This economic advantage of DDG does not automatically accrue to the distillery, but is shared by alcohol producers, cattle producers and feed manufacturers.

Numerous beef cattle feeding trials have been conducted to establish the energy values of DDG and DDGS. The energy value of DDG and DDGS is equal or slightly superior to corn grain because it contains highly digestible fiber, its protein is partially protected from rumen breakdown, and it contains three times as much fat as corn.

Even though the energy values of DDG and DDGS are high, the economic value of these products is at least twice as much when used as a protein source. This is because protein sources are more valuable than energy sources. When DDG is fed as an energy source, the protein is used as an energy source and therefore is economically underused.

Dairy Cattle

Most of the research with DDG and DDGS has been conducted with beef cattle. Dairy cattle have similar digestive systems, but there are some differences that may affect the relative value of DDG. Dairy cows consume more feed and the feed passes through the digestive tract more rapidly than in beef cattle. This may increase the bypass value of SBM and reduce the difference between SBM and DDG. The dairy cow requires more bypass protein than beef cattle and also more digestible fiber is needed to maintain milk fat test. The combination of bypass protein, digestible fiber and fat in DDG make it a highly desirable feed for dairy cows. The low starch content of DDG is also helpful because most high energy rations based on corn have in excess of that which maintains ideal rumen conditions.

Swine

The amino acid balance in DDG and DDGS is relatively poor (low in lysine) and similar to corn. Therefore the value of DDG and DDGS as protein supplements for swine is relatively low. Because DDG and DDGS are superior to SBM for ruminants and inferior for swine, it is obvious that the feeding of distillers byproducts to ruminants is preferable.

Introduction

Alcohol production from corn grain involves the fermentative conversion of starch to alcohol. The fermented mash is then distilled to remove the alcohol. The remaining slurry contains 5 to 10 percent dry matter (DM) and is called whole or spent stillage. Currently the majority of whole stillage is processed by various techniques to remove the large volume of water associated with the residual DM.

The first step involves either screening and pressing or centrifuging to remove the coarser grain particles which are then dried. This fraction is termed dried distillers grains (DDG). The liquid fraction (5 percent DM) remaining after screening or centrifuging contains fine grain particles and yeast cells and is called thin stillage. Thin stillage is generally evaporated to produce a syrup, containing 30 to 40 percent DM, which is called condensed distillers solubles (CDS). The CDS may be further dried to produce dried distillers solubles (DDS) or it may be added back to distillers grains and then the mixture is dried to form dried distillers grains with solubles (DDGS).

Two-thirds of the original grain DM consists of starch. After fermentation, approximately one-third of the original grain DM is recovered in the whole stillage. Because only the starch is removed during the fermentative process, the other nutrients associated with the grain become more concentrated. Crude protein (CP) for example increases from approximately 10 percent in the original corn grain to 27-30 percent in the whole stillage (DM basis). The nutrient composition of distillers byproducts, however, depends on the type, variety and quality of the grains used, as well as the efficiency of starch conversion and the processing technique. This paper will review the use of distillers byproducts in ruminant and swine diets. Emphasis will be placed on the evaluation of these feeds as protein and energy sources for animals in various production areas.

Distillers Byproduct Feeds for Beef Cattle

Use as Protein Sources

Early interest in DDGS as a supplement for cattle centered around its role as a stimulatory factor for ruminal fiber digestion (Little *et al.*, 1964; Little *et al.*, 1970; Beeson and Chen, 1976). These studies indicated that the addition of small amounts of DDGS, CDS or extracts from these products enhanced fiber digestion. Beeson (1975) reviewed studies which indicated that the addition of DDG, DDGS or CDS at relatively low levels (.5 percent, DM basis) to high urea liquid supplements increased nitrogen retention by ruminants. More recently, interest has been directed toward the use of distillers byproducts as protein sources for ruminants, with particular interest in the bypass value of DDG and DDGS.

Zein is the primary protein in corn DDG and DDGS. McDonald (1954) fed zein to sheep receiving semipurified diets and determined that only 40 percent of the zein was converted to microbial protein in the rumen. The remainder presumably escaped ruminal degradation. Higher protein levels were reported in the abomasal contents when lambs were supplemented with zein compared with SBM, casein or gelatin (Little *et al.*, 1968). These studies suggested that zein is degraded less in the rumen relative to SBM or other highly soluble protein sources. The degradability of corn protein in the rumen may be further decreased by heating during drying of distillers grains.

Bypass protein is that protein which escapes (or bypasses) digestion in the rumen. This protein is subsequently digested in the abomasum and small intestine of the animal, absorbed as amino acids and used for productive functions. Ruminants have two sources of protein for these functions: bypass protein and microbial protein. We must be aware of the significant role that microbial protein plays in meeting the animal's needs. In many cases, such as finishing cattle, the microbial protein sufficiently meets the animal's needs. When the microbial protein is inadequate, the only way to supply additional protein is with bypass protein. Therefore, the value of a protein source for ruminants depends upon its bypass value. Most proteins are bypassed to some extent, but some bypass more than others. Protein broken down in the rumen supplies ammonia for microbial needs. Ammonia, however, can be supplied cheaper by urea. Also proteins which are extensively broken down may yield more ammonia than is needed by the microorganism. This is absorbed and largely excreted via the urine.

Growing calves and lactating cows have high protein requirements and usually require some bypass protein to achieve maximum gain or milk production. The growing calf probably offers the best opportunity for use of high bypass protein sources with beef cattle.

Bypass values for protein sources can be determined by two basic methods: intestinally-fistulated animals and growth studies. The techniques in both types of studies are quite difficult. Various bypass values are available in the literature. It is difficult to determine which values are correct.

In the method using fistulated animals, it is necessary to use two markers. The first marker determines how much material passes through the intestines each day. The second marker estimates the proportion of the microbial protein. By difference, the amount of feed protein escaping digestion is calculated. In addition, a control ration must be used so that the protein supplied by the base ration can be subtracted.

This procedure sounds simple. Sample the digesta leaving the rumen and the protein bypassing rumen digestion can easily be determined. However, the techniques described are difficult and several errors are accumulated in calculating the bypass values. This area of research has progressed in the past few years and the values obtained most recently are probably the best. A summary of bypass values is shown in *Table II*.

Table II. Bypass values of distillers byproducts determined with fistulated ruminants.

		Bypass estimate	
Reference	**Byproduct**	**% of protein**	**% of soybean meal**
Rounds (1975)	DDGS	49	408
	DDGS	43	358
	DDGS	74	239
	DDGS	40	129
Waller (1978)	DDG	48	--
	DDGS	39	--
Brown (1983)	DDG	46	229
Firkins et al. (1984)	WDG[a]	47	--
	DDG	54	--
Santos et al. (1984)[b]	DDGS	53	182
Summary	DDG	49	229
	WDG	47	--
	DDGS	50	263

[a]Wet distillers grains.
[b]Dairy cows.

The rumen bypass value of DDGS was studied by Rounds (1975) using abomasally-fistulated wethers. Bypass values for SBM and DDGS were 31 and 40-74, respectively. Satter *et al.* (1977) measured the extent of ruminal protein degradation of SBM, DDG and DDGS using sheep fitted with duodenal reentrant cannulas. Estimates of rumen bypass of SBM and the distillers grain products were 20 and 60 percent, respectively.

Abomasally-fistulated steers were used by Waller (1978) to measure the rumen bypass values of corn DDG and DDGS. Protein bypass values calculated for DDG and DDGS were 48 and 39 percent, respectively. Brown (1983) used steers fitted with duodenal cannulas to measure the bypass values of SBM and DDG protein. Rumen bypass values were 20 percent for SBM and 46 percent for DDG.

Bypass values of the protein of distillers wet and dry grains were measured by Firkins *et al*. (1984). Bypass values were 47 percent for the wet distillers grains and 54 percent for the DDG, suggesting that drying increases the bypass value of distillers grains. Santos *et al.* (1984) fed duodenal- and ileal-fistulated lactating Holsteins a basal diet containing ground corn, oat straw and dried molasses. Bypass values for SBM and DDGS were 29 and 53 percent, respectively. Satter and Stehr (1984) reported that approximately 55 percent of DDG protein was undegraded in the rumen.

In many cases, the bypass values relative to SBM may be more important than the absolute bypass values. The average bypass value of DDG was 49 percent and for DDGS was 50 percent. As a percent of SBM, the values were 229 and 263. These values strongly support the theory that distillers products are relatively high in bypass protein and are potentially better sources of protein for ruminants than SBM. The values for DDG and DDGS cannot be directly compared because they are averages from different trials. The bypass for DDG is likely higher as will be discussed later. In the only direct comparison (Waller, 1978) the DDG was higher.

Researchers at the University of Nebraska have used the efficiency of use of supplemental protein for animal growth to evaluate distillers byproducts relative to SBM. This approach has several requirements. First, protein sources must be evaluated in diets at or below the protein requirement of the animal. Second, sufficient fermentable energy and ammonia must be available in the rumen for microbial protein synthesis. Third, the animals used to evaluate the protein sources should have a requirement for bypass protein.

Protein efficiency (PE) values are measured as the gains of animals fed the supplemental protein source minus the gains of animals fed urea as the sole source of supplemental protein divided by the amount of supplemental natural protein fed. Protein efficiency can then be determined by the ratio of the test protein efficiency value to the efficiency value of SBM times 100. A modification of this technique described by Stock *et al.* (1983), also developed at the University of Nebraska, calculates protein efficiency ratios using a protein titration approach (slope ratio).

Klopfenstein *et al.* (1978) individually fed 60 calves (539 lb) a basal diet containing 60 percent ground corn cobs and 10 percent molasses with corn added to balance for energy. Protein efficiency values for DDG and DDGS were 200 and 180 percent of SBM, respectively (*Table III*).

Table III. Protein efficiency values of distiller byproducts determined with growing ruminants.		
Reference	**Byproduct**	**Protein efficiency % of SBM**
Klopfenstein et al. (1978)	DDG	200
	DDGS	180
DeHaan et al. (1982)	WDG	248
	EWDG[a]	(169)
	WDG[b]	205
	Thin Still.	45
Waller et al. (1980)	DDGS	(200)[c]
Trenkle et al. (1981)	WDG	287
Summary	DDG & WDG	235
	DDGS	180

[a]Ensiled, not included in summary.
[b]Protein may not have been limiting.
[c]Estimated, not included in summary.

Various distillers byproducts were evaluated by DeHaan *et al*. (1982). In a lamb growth study, the PE for DDG wet distillers grains (WDG) and ensiled (EWDG) were 128, 190 and 288 percent of SBM, respectively. In a cattle growth study, thin stillage and WDG protein efficiency values were measured. Calves (500 lb) were fed a basal diet of corn silage and corn cobs (50:50 DM basis) with urea to supply 50 percent of the supplemental nitrogen. The PE for WDG and thin stillage were 205 and 45 percent of SBM, respectively. They also determined the PE for WDG and WDG treated with 2 percent $Ca(OH)_2$ (DM basis) and then ensiled. The slope ratio technique was used with steer calves (488 lbs.) fed a basal diet of 56 percent corn silage and 28 percent ground corn cobs (DM basis). Urea was added to balance all diets at 11.5 percent crude protein. Protein efficiency values relative to SBM were 248 percent for WDG and 169 percent for EWDG.

Decanted whole stillage was evaluated as a protein source for growing calves by Trenkle *et al.* (1981). Eighty crossbred steers (490 lbs.) were allotted to one of four treatments. Calves were fed a basal diet of ground corn cobs, cracked corn and molasses. Supplemental nitrogen was supplied by: (1) urea; (2) SBM; (3) corn gluten meal (CGM) + urea or (4) stillage + urea. All rations contained approximately 11 percent crude protein and 6.3 percent metabolizable protein. Daily gains for the natural protein-supplemented steers were similar but higher than the urea-supplemented steers. Steers fed SBM were more efficient than the urea fed steers but less efficient than either the CGM or stillage-fed calves.

A summary of the bypass values of DDG, DDGS and WDG based on animal gains is shown in *Table III*. This summary suggests that the bypass value of DDG and WDG is higher than DDGS. DDG has a value at least two times that of SBM and DDGS at least 1.6 times SBM.

Risk *et al.* (1982) compared SBM and WDG as protein sources for finishing cattle. Thirty-six steers

(675 lbs.) were fed corn grain *ad libitum*, 5 lbs. corn silage per head and 1.8 lbs. of a mineral-vitamin supplement. Treatments consisted of supplementation with: (1) SBM; (2) a corn based supplement with WDG to isonitrogenously replace SBM in treatment (1) or (3) a corn-based supplement with one-half the WDG fed in treatment (2). Daily gains over a 135-day period were 2.86, 2.46 and 2.75 lbs. for the SBM, WDG and one-half WDG supplemented steers, and feed/gain ratios were 5.60, 6.07 and 5.85, respectively.

Little *et al*. (1965) conducted three trials to evaluate DDGS and urea as supplemental nitrogen sources for finishing steers. The basal diet was based on a full feed of ground ear corn. Supplemental protein was supplied by SBM, DDGS, SBM + urea or DDGS + SBM. Steers receiving DDGS and DDGS + urea gained as rapidly and efficiently as steers fed SBM alone. Steers fed SBM + urea gained slower than those fed the DDGS and DDGS + urea, but efficiencies were similar. In a second study, 120 steers received a basal diet similar to that in trial one. Six treatments were supplemented with DDGS and six with DDGS urea. Additional supplementation within each protein source was vitamin A (10,000 IU), trace minerals, alfalfa meal (.5 lb./hd/day) or cane molasses (.5 lb./hd/day). Within the DDGS-supplemented diets, additional supplementation with vitamin A, minerals, alfalfa meal or cane molasses did not increase animal performance. When DDGS + urea was fed, trace minerals, alfalfa and molasses improved daily gains .13, .22 and .29 lb., respectively. In a third trial with DDGS urea-supplemented steers, no advantage was seen in cattle fed supplemental vitamin A, trace minerals, alfalfa meal or cane molasses. These studies illustrate that bypass protein is not needed for finishing cattle.

Because of the cost of drying distillers byproducts, there has been considerable interest in feeding wet distillers byproducts. However, this presents several problems. First, the dilution of nutrients by large quantities of water limits the distance these products can be economically transported. Second, the amount of dry matter that can be added to a ration from the wet products is limited, especially in silage diets. Finally, storage of the wet products, especially in warm weather, is a problem because of rapid spoilage. Ensiling the wet byproducts with dry forages may provide one solution to the problem of storage. Also the addition to a dry feed such as crop residues or hays may enable the incorporation of fairly high levels of byproduct.

Fescue hay, either untreated or treated with 4 percent NaOH (DM basis), was mixed with whole stillage such that stillage made up 0, 15, 30 or 60 percent of the total dietary DM (Hunt *et al*., 1983). The hay stillage mixtures were then ensiled for at least 20 days in small laboratory silos. Lactic acid increased with increasing stillage level. The silages were finally evaluated in a lamb digestion trial. Digestibilities increased linearly with increasing level of stillage in the silage.

Muntifering *et al*. (1983) evaluated whole stillage as a protein and energy supplement when used to reconstitute low quality fescue hay. Ground fescue hay was mixed with whole stillage or with ground corn, SBM and water and then was ensiled for a minimum of 28 days. Additional treatments were fescue hay supplemented with DDGS or corn plus SBM. All diets were isonitrogenous and supplements made up 15 percent of the diet DM. In trial one, four abomasally-fistulated wether lambs were used in a 4 × 4 Latin square design to measure ruminal and total tract digestibilities. Ruminal and total tract digestibilities of hemicellulose and neutral detergent fiber were significantly lower in the silages than in hay diets. While the authors did not identify the source of abomasal nitrogen they suggested that the higher total nitrogen reaching the abomasum in the ration with distillers byproducts may have resulted from their higher bypass value. In a second study using twenty-four lambs, nitrogen retention expressed as a percentage of intake or as a percentage of abomasal nitrogen tended to be greater in lambs fed the wet corn stillage fescue silage and DDGS supplemented hay than to the corn-SBM supplemented hay diets.

The value of fresh wet corn stillage was further evaluated as a supplemental protein source with fescue hay by Muntifering *et al*. (1985). Five crossbred lambs fitted with duodenal cannulae were used in a Latin square design. Treatments were: (1) tall fescue hay; (2) fescue hay plus fresh wet corn stillage; (3) fescue hay plus centrifuge processed WDG; (4) fescue hay plus DDGS or (5) fescue hay reconstituted with wet corn stillage and ensiled for a minimum of 28 days (EWCS). Byproducts provided an additional .06 lb. protein over that provided by the fescue hay. Supplementation with distillers byproducts significantly increased nitrogen digestibility, abomasal flow of undegraded feed nitrogen, apparent total tract nitrogen digestibility and nitrogen retention. Supplementation with EWCS resulted in greater flow of undegraded feed nitrogen to the abomasum and lower nitrogen retention compared to wet corn stillage supplementation. Ruminal feed nitrogen digestibility was similar for lambs fed wet corn stillage, WDG or DDGS. Ruminal nitrogen digestibility was higher for lambs fed wet corn stillage compared to EWCS. The authors concluded that ensiling offered a means of storing wet corn stillage, thus saving drying costs, but feeding value was reduced compared to fresh wet stillage.

Volatile fatty acid production was minimal when WDG alone were ensiled without alkali addition (Abrams *et al*. 1983). However, soluble nitrogen increased and some lactate initially present in the WDG was consumed. Additions of alkali, (NH_4OH and $Ca(OH)_2$) regardless of source, resulted in a butyric acid type of fermentation, with associated production of acetate and propionate. The changes observed in ensiled WDG with alkali treatment are characteristic of a clostridial fermentation, expected from proteinaceous substrates that have little readily available carbohydrates.

In silages, a butyric acid fermentation is typically accompanied by an increase in soluble and ammonia nitrogen, increased amino and keto acid production and, in some instances, decreased palatability. The latter may not occur when the ensiled feed is used as a protein supplement, because dilution of the ensiled feed by the principal dietary components may mask the unpalatable characteristics. As indicated previously, (DeHaan *et al*., 1982) ensiling reduces the bypass value of WDG (*Table III*).

Thin stillage is a byproduct of the production of alcohol from grains and results from the separation of whole stillage by screening, pressing, or centrifugation. A limited amount of research has been conducted regarding the potential use of uncondensed thin stillage as ruminant feed.

Thin stillage may contain up to one-third of the total byproduct dry matter (DM) and contains about 28-30 percent crude protein (CP), 1.4 percent phosphorus, 2.10 percent potassium and .30 percent calcium, on a DM basis. The nutrient content may vary depending on grain source, processing equipment and the efficiency with which starch is converted to alcohol. The DM content of thin stillage is 4-8 percent and will vary with fineness of grind of the grains before fermentation, size of screen used, if screening is the technique of separation of whole stillage, and the technique used for separation. The high moisture content poses transportation and handling problems. In addition, the high moisture content places limitations on the amount of thin stillage DM that can be included in the diet. An alternative to feeding thin stillage wet is to dry the material back onto the wet grains. This, however, requires a large input of energy and is costly.

Because of limited research on the use of thin stillage in ruminant diets, four trials were conducted to evaluate its potential use as a feed source. Two trials were conducted with cattle and sheep to test the effect of increasing thin stillage levels in the diet on intakes. A third trial using sheep was performed to test the effects on intake of neutralizing thin stillage and ensiling thin stillage reconstituted cornstalks before feeding. A cattle growth trial was also conducted to evaluate thin stillage as a supplemental protein source (Aines *et al*., 1985).

Results indicated that increasing thin stillage in the diet up to 10 percent of the DM did not significantly affect intake. The high moisture content of thin stillage made it impractical to test higher levels. Intake of a water reconstituted cornstalk diet (control) was 3.25 percent of body weight. This was not different from the average intake of the diets containing thin stillage reconstituted cornstalk diets. Comparison of the thin stillage and neutralized thin stillage diets indicated that neutralization did not affect DM intakes.

Ensiling of thin stillage reconstituted cornstalks depressed intake. Thin stillage has a PH of 3.5 to 4.5. This is a concern relative to intake when fed fresh and the ensiling process and subsequent intakes of the ensiled material. Calcium hydroxide ($Ca(OH)_2$) was selected as a neutralizing agent following laboratory studies which indicated that relatively small amounts of $Ca(OH)_2$ (.36 lb./100 lbs. thin stillage) were sufficient to raise the pH to 6.0.

Ensiling cornstalks or other crop residues reconstituted with thin stillage would provide large quantities of thin stillage to be mixed and stored for later feeding. Laboratory studies indicated that mixing thin stillage with cornstalks at a level of 10 percent (DM basis) produced an initial pH in the material of 6.1. The cornstalks apparently buffer the acids of thin stillage. After 21 days of ensiling, the pH of the material was 4.58, indicating that fermentation had occurred. The stability of this mixture over time was not examined. Results of a lamb trial suggest that ensiling depresses intake compared to feeding fresh material.

Growing calves fed SBM tended to have improved daily gains and feed efficiencies, compared to control (urea-fed) animals. Thin stillage-fed animals performed intermediate to the control and SBM treatments.

Incorporation of thin stillage into ruminant diets does pose problems. If thin stillage is produced at a site off the farm, it must be transported. This means hauling large quantities of water to get a small amount of DM. Whether produced on the farm or shipped in, thin stillage requires special storage and handling facilities. Incorporation of relatively small amounts of DM from thin stillage into a diet means adding a large amount of water to the diet. This limits the amount of thin stillage that can be fed, especially in diets where a wet feed such a corn silage or feeds with limited absorptive capacities such as grains are fed. Settling and removal of surface water before feeding can increase the amount of DM provided in the diet from thin stillage. However, this increase will be slight since settled thin stillage still contains 90 percent moisture or more. In these experiments, no advantage, in either intake or gain, could be attributed to feeding thin stillage. However, incorporation of thin stillage did not appear to adversely affect intake or animal performance at the levels fed.

Researchers at the University of Minnesota (Hanke *et al*., 1982b) conducted studies in which thin stillage replaced drinking water for finishing cattle. In a summary of three finishing trials, they reported that steers receiving thin stillage in place of drinking water gained .20 lb./day more, consumed 1.44 lbs. DM/day less and required 78 lbs. less DM feed/100 lbs. gain than to steers drinking water. This approach to thin stillage use may be a viable alternative to incorporating thin stillage into rations.

Table IV. Energy value of distillers grains for beef cattle.

Reference	**Level in ration, % DM**	**Energy value, % of corn**
Rouse and Trenkle (1980)	15	116
Farlin (1981)	25	100
	50	124

	75	115
Hanke et al. (1982a)	14.6	94
Risk et al. (1982)	10.5	83
	24.9	122
	43.6	110
Firkins et al. (1985)	25	103
	50	122
Summary		109

Distillers Grains as an Energy Source

Rouse and Trenkle (1980) substituted decanted whole stillage for 15 percent of the corn (DM basis) in a finishing diet fed to crossbred heifers (750 lbs.) (*Table IV*). The basal diet contained rolled corn, corn cobs and molasses. Urea was added to both diets to balance for 12.5 percent crude protein. Heifers fed the stillage diet gained as fast (3.45 lbs./day) as those receiving the control diet (3.43 lbs./day). Feed conversions were also similar between the two diets (6.56 and 6.41 for the control and stillage-fed heifers, respectively).

Wet distillers grains were fed to replace 0, 25, 50 or 75 percent of the corn (DM basis) in a finishing diet by Farlin (1981). The resulting diets contained 0, 21, 43 and 64 percent WDG dry matter. The control diet contained 85 percent corn, 10 percent hay and 5 percent supplement. Protein levels ranged from 11 percent for the control to 22.7 percent for the highest level of WDG. Urea was removed from the supplement when WDG was included in the ration. At the 21 percent WDG level, feed intake, daily gain and feed efficiencies were not different from the control-fed cattle. At the 43 percent WDG level, feed intake was not affected but daily gains increased 10 percent and feed efficiencies increased 10.6 percent. When WDG replaced 75 percent of the corn in the diet, feed DM intakes were reduced 11 percent but gains were equal to the control diet and feed efficiencies increased 10 percent over the control.

Risk *et al.* (1982) evaluated WDG as an energy and protein source for finishing beef heifers. One hundred crossbred heifers (535 lbs.) were fed a control ration of 5.5 lbs. corn silage, 4 lbs. of a mineral-vitamin supplement per head per day and *ad libitum* corn grain. Treatments were: (1) SBM control; (2) WDG to replace SBM; (3) WDG fed to replace SBM and one-half the grain and (4) WDG fed to replace SBM and all the corn grain. Daily gains were not significantly different for the SBM and two lower levels of WDG supplemented steers (2.84, 2.82 and 2.75 lbs./head/day, respectively). When WDG replaced all the corn grain in the diet, daily gains were significantly reduced (2.49 lbs./head/day). Dry matter intakes tended to decrease with higher levels of WDG but feed efficiencies tended to increase.

Pressed WDG were evaluated as a protein and energy source using fifty yearling steers (950 lbs.) by Hanke *et al*. (1982a). Half the steers were fed a finishing diet of 10 lbs. corn silage and 1 lb. of a corn/urea-based supplement (wet basis) plus high moisture corn *ad libitum*. The other steers received 10 lbs. corn silage, 1 lb. of a corn-based supplement (no urea) and 10 lbs. WDG (wet basis) plus high moisture corn *ad libitum*. Daily gains were 3.52 lbs./day for the control fed steers and 3.30 lbs./day for the WDG fed steers. The WDG fed steers consumed less DM (24 lbs./day) than to control steers (26 lbs./day) and feed efficiencies were similar for both treatments.

Firkins *et al*. (1985) conducted a finishing trial with 132 crossbred steers (682 lbs.) to evaluate WDG as an energy source. They were fed a basal diet consisting of 13 percent chopped hay, 72 percent high moisture corn and 14.8 percent supplement. Wet distillers grains were added at 0, 25 or 50 percent (DM basis) of the diet, replacing SBM and high moisture corn. Daily gains and feed efficiencies increased linearly with increasing level of WDG fed. Daily gains were 2.38, 2.53 and 2.64 lbs./day for the 0, 25 and 50 percent levels, respectively. The authors suggested that the improvement in performance of steers fed WDG was due to a higher digestible energy value for WDG than suggested by NRC (1976) or that the absence of starch in WDG may have resulted in a higher rumen pH relative to the control and consequently fiber digestion may have been improved. Another contributing factor may be decreased acidosis in cattle fed WDG, although this has not been examined. These studies would suggest that feeding WDG as a substitute for grain in finishing cattle at replacement levels up to 50 percent do not result in decreased animal performance and in fact suggest better performance.

Generally, fiber content of a feedstuff has been considered a disadvantage. That is, as a general rule, the higher the fiber content, the lower the energy. This generalization is based on the lower digestibility of forages compared to high starch concentrates and that hulls of many seeds such as sunflower, rice and cottonseed are generally low in digestibility. There are several exceptions to this generalization, one being that corn fiber (bran) is highly digestible. DeHaan *et al*. (1983) reported corn fiber was both highly (87 percent) and rapidly (6.2 percent/hr) digested.

Corn contains about 12 percent fiber (neutral detergent fiber) and with starch removal, DDGS contain about 35 percent fiber. Cereal grains are generally used to supplement forages to increase the energy content of ruminant rations. However, starch digestion in the rumen lowers pH and reduces fiber digestion. This is called a negative associate effect. As a result, the ration provides less energy than would be predicted. This is important in growing beef rations and especially important in dairy rations. By necessity, dairy rations are a mixture of grain and forage.

Klopfenstein *et al*. (1985) compared corn bran and corn grain as energy supplements in high forage rations (*Table V*). Calves ate more feed, gained faster and were more efficient when 25 and 50 percent of a corn cob and alfalfa ration were replaced by either energy supplement. Calves ate more ration dry matter when fed corn, but tended to be more efficient (5 percent) when fed corn bran. Digestibility of a brome hay ration increased with the 25 percent level of energy addition, but increased no further at the 50 percent level. Rumen pH values and fiber digestibilities suggested that corn grain decreased fiber digestibilities markedly. Bran did not reduce fiber digestion at the 25 percent level, but did at the 50 percent level. Corn bran appeared to be at least equal to corn as an energy supplement for forage rations. This suggests the energy value of distillers byproducts for ruminants is as high as corn and may in fact be even higher than corn in roughage rations.

Table V. Feeding value of corn bran.

Item	**Control**	**25% Bran**	**50% Bran**	**25% Corn**	**50% Corn**
Digestion Trial:[a]					
----Intake[b], lb/d	12.2	12.4	14.0	14.4	17.5
----Dry matter Digestibility[c], %	49.5	59.4	57.5	56.6	56.6
----Predicted DM Digestibility[d], %	50.7	57.8	65.1	60.7	70.7
----Associative Effect[e]	-1.2	1.6	-7.6	-4.1	-14.1
----NDF Digestibility, %	49.3	58.2	57.1	50.4	45.1
----Rumen pH[c] (8 hr.)	6.22	5.66	5.22	5.54	5.29

Growth Trial[g]:					
----Intake[h], lb/d	9.6	11.4	12.2	11.7	15.0
----Daily gain[h] lb	.87	1.85	2.36	1.80	2.72
----Gain/Feed[i]	.10	.16	.19	.15	.18

[a]Control ration brome hay, fed to 669 lb steers.
[b]Significant energy level and source effects ($P < .01$).
[c]Energy level effect ($P < .05$).
[d]Based on in vitro dry mailer disappearance.
[e]DM digestibility minus predicted DM digestibility.
[f]Energy source ($p < .05$).
[g]Control ration, 75 percent corn cobs, 25 percent alfalfa haylage plus supplement fed so 550 lb calves.
[h]Energy level × source interaction ($P < .01$).
[i]Linear effect of level ($P < .001$).

Energy Summary

The preceeding trials are summarized in *Table IV*. This summary suggests that DDG and DDGS have energy values about 9 percent better than corn. A conservative estimate then is that the energy value of these byproducts is at least equal to corn.

Ration Formulation

Several systems that account for bypass protein have been proposed. A comprehensive system will eventually be developed that will more accurately formulate rations. At the present time, accurate values for feedstuffs and animal requirements are being developed, but don't seem to be ready for widespread use.

Currently used protein systems (NRC) reflect values developed primarily with SBM. We propose using the present system with the incorporation of SBM equivalent values (SBME). This can be readily programmed into most computers. Presently, most computer programs have constraints on urea use. This can be replaced by a SBME requirement. In a growing beef ration where no urea is used, the SBME requirement would be equal to the crude protein requirement. In a ration where 1 percent urea is allowed, the SBME requirement would be 2.81 percentage units less than the crude protein requirement. The SBME value for all feedstuffs would be equal to the crude protein value except for protein sources that have been specifically tested. The SBM equivalent value for DDG, for example, would be (29.5 percent crude protein in DDG × 2) 59 SBME (*Table VI*). The multiplier of two is because the protein in DDG has been proven to be worth twice a unit of protein in SBM. Urea would be zero. The computer then balances for both crude protein and SBME. Once the SBME requirement is met, urea is used to complete the crude protein requirement (*Table VII*).

Table VI. Protein values of distillers byproducts.

	Distillers grains	**Distillers grains plus solubles**
Crude protein, %	29.5	29.6

Soybean meal equivalent[a]	59.0	47.4
Plus corn[b], %	15.5	--
Plus urea[b], %	8.4	7.2
[a]Value relative to SBM. Calculated by multiplying % crude protein times bypass values (% of SBM); 2 for DDG and 1.6 for DDGS. [b]DDG or DDGS plus corn and urea (total 100%) equal to soybean meal in protein and energy.		

Table VII. Bypass supplement using soybean meal equivalent (SBME)					
Ingredient	**% of supp.**	**% CP[a]**	**lb CP**	**% SBME[b]**	**lb SBME**
DDG	67.6	26.6	18	53.3	36
Wheat midds	23.2	17	4	17	4
Urea	6.4	281	18		
Minerals	2.8		--		--
			40		40
[a]As is basis. [b]Crude protein times relative protein value (*Table V*).					

Three computer-formulated rations are shown in *Table VIII*. An all natural 40 percent protein supplement using SBM is shown which had ingredient costs of $150/ton. A comparable supplement using DDG sources cost $100/ton. If our assumptions are correct, the two supplements are equal in feeding value. A 40 percent supplement using DDGS would cost $116/ton. A small amount of a high protein, high bypass protein (blood meal) was needed to balance the supplement be cause DDGS is lower in bypass protein than DDG.

Table VIII. "All Natural" beef supplements[a]					
Normal 40%		**Bypass 40% (DDG)**		**Bypass 40% (DDGS)**	
SBM	84.5%	DDG	67.6%	DDGS	88.5%
Midds	14.5	Midds	23.2	Blood meal	2.3
Minerals	1.0	Urea	6.4	Urea	5.2
		Min.	2.8	Min.	4.0
$150/ton		$100/ton		$116/ton	
[a]Prices per ton: SBM $165; DDG, $100; Blood meal, $295; Urea, $210; Midds, $61.					

The advantage of using the bypass protein system is economics. This is because: (1) the amount of natural protein fed is reduced; (2) the use of urea is increased; (3) this results in lower cost of supplementation, yet performance is maintained. Assuming that the animal's protein requirement was met on the previous "all natural" supplement, performance could not be increased, it could only be done at a lower cost.

What should a cattle producer expect from a commercial bypass protein supplement such as those containing DDG? It should be sold at a lower cost. The cost/ton may be as high or higher than a conventional "all natural" supplement, but if it is higher in crude protein, the feeding rate will be lower. Therefore, the cost per head per day should be lower. If the supplement is not cheaper, the feed company is taking all the economic benefit of the bypass protein concept. A bypass supplement is recommended for growing calves and maybe lactating cows, but not for finishing cattle. The producer should expect gains similar to previous "all natural" supplements and should be wary of claims for increased gain.

We are enthusiastic about the application of the bypass protein concept because it offers economy to the cattle producer with essentially no risk of reduced performance or any problems. It is definitely not a matter of returns per dollar spent, but rather an opportunity for cutting costs. Those feed companies which have been using this concept for the past year or two indicate excellent results. This, as much as the research conducted, assures us that the concept is valid.

Conventional systems are sufficient for the use of the energy values for distillers products. The summary in *Table III* suggests that the energy values for DDG (or wet DG) and DDGS are: TDN, 87; NEm, .95 and NEg, .65 respectively based on 1976 NRC values.

Distillers Byproducts for Dairy Cattle

Loosli *et al*. (1952) compared corn gluten feed (CGF), DDG and DDGS as protein sources for dairy cows that had recently passed their lactation peak. In the first trial, cows produced 3.1 lbs. more 4 percent fat-corrected milk when fed DDGS and 2.5 lbs. more 4 percent fat-corrected milk when fed DDG than when receiving CGF. Similar but smaller differences were observed in a second trial. Feed intakes were not different for the two protein supplementations.

Cows that had recently passed peak lactation and were fed DDGS or SBM,\ produced more 4 percent fat-corrected milk than cows fed linseed oil meal (Loosli, 1960). In a subsequent study, Loosli *et al*. (1961) fed either DDGS or SBM to lactating dairy cows past their peak lactation. No differences in total milk, milk fat or 4 percent fat-corrected milk were detected. Loosli (1960) summarized ten trials in which DDG, DDGS and distillers solubles were used as protein sources for lactating dairy cows. Cows receiving DDGS produced more milk in each of the four studies in which it was compared to other protein sources. Supplementation with DDGS was superior to urea in two studies and in another two studies cows produced more fat-corrected milk when supplemented with DDGS than with linseed oil meal.

McCullough (1962) in a series of four trials with lactating dairy cows reported that feeding wheat silage to which was added at least 100 lbs./ton of corn DDG at ensiling significantly improved fat corrected milk production.

Voelker (1981) fed stillage to dairy cows to replace all the SBM and 10 lbs. of grain mix. Total DM intake was not different between the control and stillage-fed cattle. Milk production, percent fat and protein and total milk solids were similar between treatments. Schingoethe *et al*. (1983) fed WDG at a level to replace 10 lbs. of a concentrate mix and all the SBM normally included in the concentrate mix to lactating cows 12 weeks postpartum. Milk yields and composition of milk were similar for the SBM control and WDG-supplemented cows.

Twenty-four lactating cows (16 Holsteins and 8 Jerseys) were fed one of three concentrates (Palmquist and Conrad 1982). Concentrate mixes were: (1) a negative control based on corn, oats and SBM: (2) concentrate (1) plus 7 percent blended animal-vegetable fat (positive control) or (3) concentrate (1) plus DDGS to replace SBM and oats. The cows were started on trial on the 4th day of lactation and the experiment lasted 45 days. The concentrate mixes made up 50 percent of the ration DM. The addition of DDGS tended to decrease production in the Holsteins and increase production in Jerseys. Milk protein was significantly decreased in Jersey cows fed DDGS. Decreases in plasma lysine, threonine, arginine, glycine and alanine plus the decrease in milk protein in DDGS-fed cows suggested that protein digestibility of DDGS was low. An amino acid imbalance, particularly for lysine may have contributed to decreases in performance.

Satter and Stehr (1984) noted that despite a higher bypass value for DDG the amount of lysine reaching the small intestine would be less than in SBM-fed cows while methionine reaching the lower gut would be greater. Since lysine and/or methionine are probably first limiting in high producing dairy cattle, they suggested that lysine would probably be the first limiting amino acid in cows fed DDG. A trial was conducted comparing (1) SBM, (2) a mixture of extruded soybeans and SBM, (3) a combination of DDGS and CGM and (4) equal parts of (2) and (3). The cows were on test between days 11 and 40 of lactation. Milk production was used to evaluate the protein supplements. The highest milk production occurred with the extruded soybeans + SBM supplement followed by the SBM treatment. The mixture of extruded soybeans + SBM and DDGS + CGM resulted in milk production levels intermediate between SBM and DDGS + CGM which resulted in the lowest level of milk production. Lysine may have been limiting and the high bypass value of the DDGS + CGM supplement did not overcome this deficiency. The authors did caution that the DDGS + CGM and the mixture of extruded soybeans + SBM and DDGS + CGM may have been biased against since these diets had lower rumen ammonia levels (<5 mg NH_3-N/100 ml rumen fluid) at four hours post feeding. Consequently, microbial protein synthesis may not have been maximized.

Recently Van Horn *et al*., (1985) obtained poorer performance from lactating cows when DDGS was fed than when SBM was fed. However, their DDGS appeared to be over-heated in the drying process which resulted in depressed protein and energy digestibilities.

The experiments conducted with dairy cattle have not met the criteria mentioned previously for beef cattle; protein limiting, etc. Therefore it is difficult to draw conclusions as to the comparative values of distillers products and other protein sources.

We cannot directly transfer data obtained with beef cattle for use with dairy cows. While the cow has a greater protein need, there are several factors that must be considered. The level of feed intake by the dairy cow is high and likely results in somewhat faster passage of feed through the digestive tract. This may decrease the difference between SBM and DDG as protein sources. Also high producing cows with high protein requirements must be fed fairly high grain levels. This reduces rumen pH and may reduce rumen protein degradability. Again this would reduce the bypass advantage of DDG.

The information presented and the experience from several feed companies suggests that DDG have a higher protein value for dairy cows than SBM when used in rations balanced to benefit their use. At the present time we cannot confidently use the same SBME values on DDG and DDGS for dairy cows as we use for beef, but they can serve as a starting point.

The energy value of DDG and DDGS for dairy cows is likely equal to corn (*Table I*) and may be superior. The fat content and the highly digestible fiber are advantages and because much of the protein bypasses rumen digestion, it reduces the acid load in the rumen and serves as an efficient energy source.

Again, economics will usually favor its use as a protein source rather than as an energy source.

Distillers Byproducts for Swine

Distillers dried grains plus solubles contain approximately 27 percent crude protein, but are low in lysine and tryptophan. Harmon (1974) studied the availability of lysine and tryptophan in corn DDGS for young growing pigs. Two studies were conducted to evaluate tryptophan availability and three to evaluate lysine availability. The basal diet in all studies was corn and SBM. In a 2 × 4 factorial study, DDGS contributed 0, 15.2, 30.7 or 46.3 percent of the dietary tryptophan and D, L-tryptophan was supplemented in all diets at levels of either 0 or .03 percent. Pigs (24 lbs.) gained more slowly as DDGS increased in the diet. Addition of .03 percent D, L-tryptophan did not affect growth, indicating that tryptophan was not limiting. In a second trial, DDGS contributed 0 or 15.2 percent of the dietary tryptophan and D, L-tryptophan was supplemented at either 0 or .08 percent. Addition of supplemental tryptophan again did not improve performance.

Two studies were conducted to determine if the decrease in performance with increasing DDGS observed in trial one was due to lysine deficiency. Distillers dried grains with solubles were fed at levels of 0, 5, 10, 15 or 20 percent of the diet and lysine·HCl was decreased in the diet to maintain a constant lysine level. The control diet contained .62 percent lysine and the lysine level decreased .009 percent with each 5 percent addition of DDGS. Performance decreased linearly with increasing level of DDGS. In a third trial, DDGS was fed at 0 or 8 percent of the diet and either 0 or .12 percent lysine was added. In heavier pigs (128 lbs.), no response was observed due to lysine supplementation in the DDGS fed pigs.

Harmon (1975) reported equal performance in 33-lb. pigs fed corn-sesame meal basal diets when DDGS were fed at 0, 5, 10, 15 or 20 percent of the diet. Lysine·HCl was reduced to maintain an equal level of lysine in all diets. Similarly, in wheat-SBM diets pigs performed equally well when fed 10 or 20 percent DDGS or lysine HCl to provide an equal amount of lysine in the diet.

Forty-eight crossbred pigs (39 lbs.) were fed a 15 percent crude protein corn-SBM control diet or the control diet with 5, 10 or 20 percent DDGS replacing corn and SBM on an isonitrogenous basis (Wahlstrom *et al*. 1970). No differences were observed in daily gains, but feed efficiency decreased significantly when 20 percent DDGS was fed. Protein digestibility tended to be lower in pigs receiving DDGS.

In a second study, one hundred crossbred pigs were fed the same diet as in experiment one except that fat was added to the diets containing DDGS to balance for energy. Diets were fed with or without supplemental lysine to balance all diets for .75 percent lysine. No differences were observed in intake, gain or feed efficiency between treatments. In a third trial, sixty-four crossbred pigs (39 lbs.) were fed the corn SBM-basal diet, the control diet plus 20 percent DDGS, the DDGS diet plus .15 percent lysine HCl or the DDGS diet plus .25 percent lysine HCl. Pigs fed the unsupplemented DDGS diet gained slower and were less efficient compared to the other diets. No differences were observed between the control diet and either lysine supplemented DDGS diet.

Wahlstrom and Libal (1980) conducted two trials with 120 crossbred pigs (39 lbs.) in each trial. A basal diet of corn and SBM was fed with either 0, 10, 20 or 30 percent DDGS to replace corn and SBM. Diets were balanced for 19.6 percent crude protein and 1.05 percent lysine. Daily gains decreased linearly with increasing level of DDGS in the diet. Feed intake and feed efficiencies were not different between treatments.

These studies show that the protein in DDG and DDGS has less quality (amino acid balance) than SBM. To be economical for use with swine (poultry are similar) DDG and DDGS would need to be considerably cheaper than SBM.

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File MP51 under: FIELD CROPS
Miscellaneous Crops
1986

The Agricultural Research Division
Institute of Agricultural and Natural Resources
University of Nebraska-Lincoln

Darrell W. Nelson, Director