Storage of Wet Corn Co-Products

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A joint project of the Nebraska Corn Board and the University of Nebraska–Lincoln Institute of Agriculture and Natural Resources

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Agricultural Research Division
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STORAGE OF WET CORN CO-PRODUCTS

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Opportunities For Storage

Three types of distillers grains can be produced that vary in moisture content. Ethanol plants may dry some or all of their distillers grains to produce dry distillers grains plus solubles (DDGS; 90% dry matter [DM]). However, many plants that have a market for wet distillers locally (i.e., Nebraska) may choose not to dry their distillers grains due to cost advantages. Wet distillers grains plus solubles (WDGS) is 30-35% DM. Modified wet distillers grains plus solubles (MWDGS) is 42-50% DM. It is important to note that plants may vary from one another in DM percentage, and may vary both within and across days for the moisture (i.e., DM) percentage. Figure 1 depicts different forms of distillers grains that may be used by beef producers. There are advantages and disadvantages to each of these feeds.

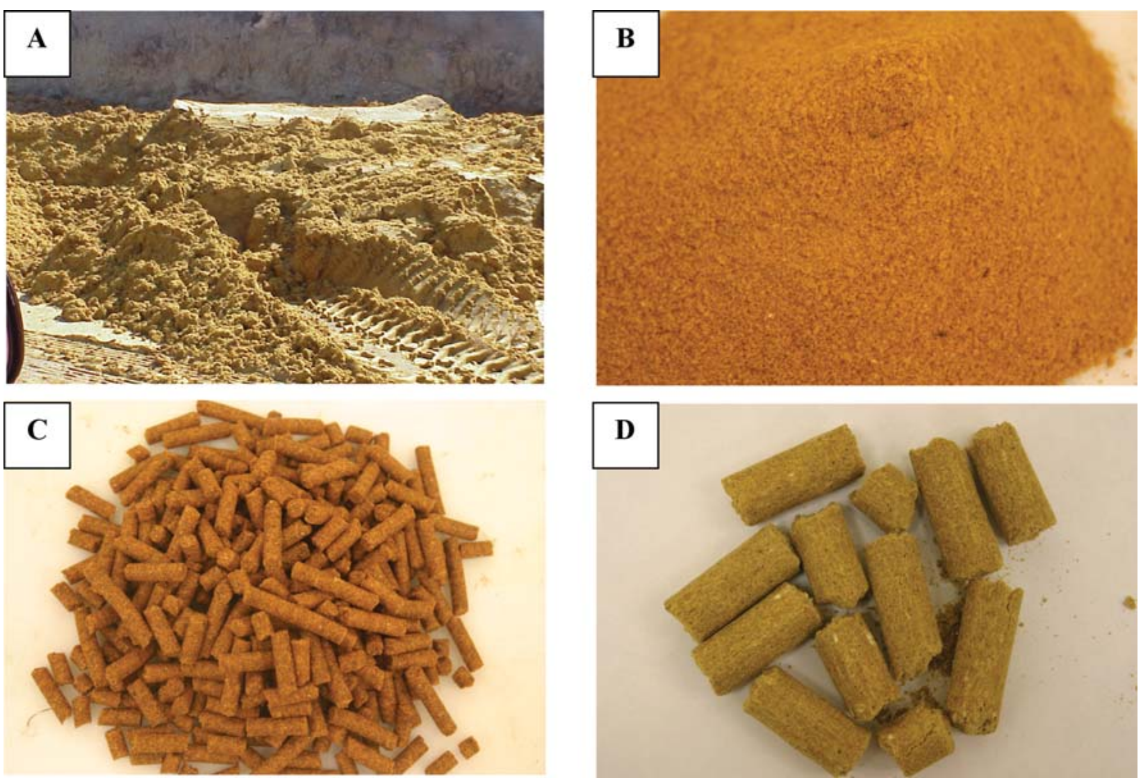

Figure 1. Different forms of distillers grains: A. WDGS (approximately 35% DM), B. DDGS in a meal form (90% DM), C. DDGS in a pelleted form (3/8 in. pellet, 90% DM, approximately 96% DDGS) and D. DDGS in a cube form (3/4 in. cubes, 90% DM, approximately 70% DDGS).

Storage of Wet Corn Co-Products

Another type of feed is wet corn gluten feed (WCGF). There are predominantly two main types of WCGF, which vary in composition and moisture content. In general, these two feeds can be divided into commodity WCGF (40-45% DM) and Sweet Bran (a specific WCGF made by Cargill; 60% DM). These feeds have different storage properties compared to WDGS, and will be discussed briefly throughout this manual.

For a more complete review on feeding of distillers grains and corn gluten feed to beef cattle, the reader is referred to a similar publication produced by the University of Nebraska–Lincoln Extension in cooperation with the Nebraska Corn Board. The Utilization of Corn Co-Products publication can be found at: beef.unl.edu or www.nebraskacorn.org.

One challenge with WDGS, MWDGS or WCGF is shelf life. Spoilage will usually begin on the surface of piles of these wet co-products from 3 to 14 days while exposed to air. Shelf life or stability may also vary with ambient temperature, with shorter shelf life existing in hot conditions. While this is avoidable or can be minimized in cases where feed is fed relatively fresh in large feedlots, this may limit the use of WDGS, MWDGS or WCGF for smaller operations. In most cases, milling plants would prefer to deliver co-product in semi-load quantities (25-30-ton loads) making it difficult for smaller feedlots (less than 1,000-head capacity) to feed a large enough quantity to avoid some spoilage. Likewise, cow-calf producers may want to use WDGS, MWDGS or WCGF, but on a seasonal basis. Seasonal usage is quite difficult for milling plants to manage as their production is fairly constant throughout the year.

Another challenge facing milling plants is the seasonality of cattle numbers in feedlots. Figure 2 depicts the cattle-on-feed numbers for feedlots greater than 1,000 head capacity for the U.S. For the previous five years, cattle-on-feed may fluctuate across months by as much as 1.5 million head. The trend is for fewer cattle in feedlots during summer months. Seasonality of cattle in feedlots is likely even more dramatic in Nebraska than other parts of the U.S. As a result, demand for and price of distillers grains (reported in Figure 2 as DDGS) is usually the lowest during the summer months when cattle-on-feed numbers are lowest. The price for WDGS likely fluctuates even more during the course of a year; however, price data are not available for multiple year comparisons of seasonality in price.

Therefore, it is logical that seasonal users of WDGS, MWDGS or WCGF may choose to store large quantities for use at a later date. Similarly, smaller operations that cannot use semi-load quantities at a rate that prevents

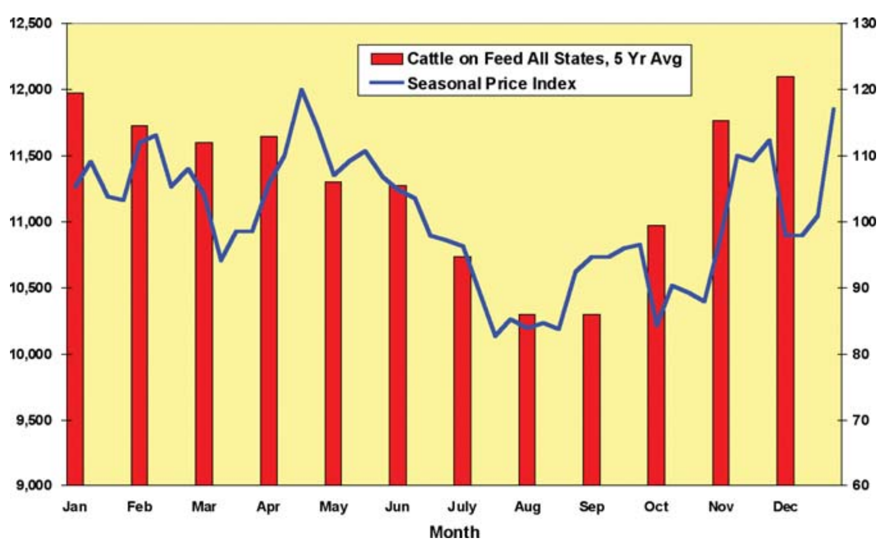

Figure 2. Price of distillers grains by month for DDGS from 2003 to 2006 with cattle-on-feed by month from 2003 to 2007 for the U.S. (Waterbury and Mark, 2008). Cattle-on-feed data are adapted from USDA National Agricultural Statistics Service whereas the DDGS price series data are adapted from USDA Agricultural Marketing Service "Corn belt feedstuffs report."

spoilage may choose to store these wet co-products. Lastly, any operation regardless of size may choose to purchase large quantities of WDGS or MWDGS in the summer when prices are traditionally the least expensive and feed throughout the remainder of the year. For all of these reasons, storage of wet corn co-products is an important management practice that beef producers may want to learn more about.

We initiated storage tests in 2006 to give producers a "starting point" to store these wet co-products at their operation. Since then, many producers have successfully stored WDGS, MWDGS or WCGF. This manual is intended to give producers a starting point and to share different methods of storing wet co-products.

Storage Concept

The process of storing wet co-products is not much different, at least in process, from ensiling (storing) either corn silage or high-moisture corn. Oxygen is the enemy. Therefore, excluding air is key whether you are using a bunker storage facility or silo bags. It is not clear how much anaerobic fermentation occurs during storage. The WDGS and WCGF are acidic, having a low pH (pH of 4-4.5 are not uncommon). Therefore, fermentation is likely minimal due to very acidic conditions. Theoretically, if all the air is excluded, storage can occur indefinitely with no spoilage losses. However, there may be some air exchange at least on the surface in bunker storage facilities. When wet co-products are mixed with forage, there may be fermentation of the forages but this has not been well documented.

The main challenge with storage of WDGS (35% DM, 65% moisture) is that the material is not able to be compacted during storage. Therefore, bulking agents are needed to either dry the material, to add bulk or both. Dry forages are the most logical source to add bulk to WDGS. However, other dry feeds may be used. Modified WDGS and WCGF appear to have enough bulk to be able to store in silo bags under pressure (300 psi or greater). It should be noted that WDGS (35% DM) can be stored in silo bags under no pressure with little risk of splitting bags (Figure 3). However, this storage method is less efficient in terms of storage area and use of bags and may allow for some air pockets with no pressure added to the bag.

Figure 3. Bagging straight WDGS with no pressure. WDGS can be bagged with no forages or other feeds added; however, the bagger cannot apply pressure during bagging.

Silo Bag Storage

Storage of WDGS by itself in bags under pressure (300 psi or greater) can result in splitting bags (Figure 4). If splitting is going to occur, the problem usually occurs relatively soon after bagging (within a few days). Therefore, the objective of these storage tests was to add different feeds to allow for bagging under pressure with little risk of splitting the bags.

Different amounts, as well as types of forage or dry feeds, were evaluated by combining with WDGS. The WDGS in this test was 34% DM. Traditional WDGS were mixed using a truck mounted feed mixer with weighing capability. During all of the bagging experiments, the bagger was held at a constant pressure of 300 psi. All of the grass hay, wheat straw and corn stalks were ground through a tub grinder with a 5-inch screen; alfalfa hay was ground with a 7-inch screen. Feed products used in the experiments contained different DM, therefore all percentages are presented on a DM basis.

WDGS (34% DM) were mixed with one of five different feedstuffs, including grass hay, alfalfa hay, wheat straw, DDGS and WCGF. During the experiment, adjustments were made based on how the different products bagged. Grass hay was tested at 17.5, 15, 12.5, 10 and 7.5% with the remaining percentages in each case being WDGS on a DM basis. Alfalfa hay was tested at 25, 22.5, 20, 17.5 and 15% on a DM basis with increasing percentages of WDGS. Wheat straw was mixed with WDGS at 15% and 12.5% (DM basis). Ratios of DDGS:WDGS evaluated were 50:50 and 60:40 (DM basis). WCGF was mixed with WDGS at ratios of 40:60 and 50:50, respectively (DM basis). Figure 5 depicts some of the different mixtures performed during bagging. Figure 5 illustrates that we did not provide enough forage or bulk in some cases.

To determine the amount of feeds to weigh out, producers need to accurately account for the mixture needed on a DM basis, and then calculate the as-is percentages so that feeds can be weighed out. This process is similar to combining feeds at the time of feeding into mixing equipment. With wetter feeds such as WDGS, the as-is percent inclusion of forage is significantly less than the mixture on a DM basis.

Figure 4. Consequence of bagging straight WDGS under pressure (300 psi) or without enough forage or other bulking agents to allow for pressure during bagging.

Figure 5. Bagging WDGS with experimental mixtures of different forages and amounts of forage. This picture illustrates the different height and width of silo bags depending on forage or dry feed added. We evaluated the lower limits required and did break the bag when too little forage was added.

Table 1 provides example calculations for determining the mixture on an as-is basis from the mixture provided on a DM basis, along with the DM of each ingredient.

The minimum amounts of forage needed for bagging under pressure are likely dictated by the fiber content of the forage. It appears that forages are the best choice to add bulk and allow for bagging under pressure. Lower quality forages (i.e., more fibrous or greater neutral detergent fiber [NDF] content) such as wheat straw and corn stalks are probably better suited for this storage method than more digestible, higher quality forages. Forage sources can likely be exchanged on an equal fiber basis, but this has not been well established given the difficulty researching all the possible combinations of WDGS and forages available.

Interestingly, it does not require a great deal of forage to add enough bulk to keep bags from splitting when bagged under pressure. Our data would suggest that minimum amounts of wheat straw (and presumably corn stalks) are a mixture of 12.5% wheat straw with 87.5% WDGS (DM basis). On an as-is basis, this equates to approximately 5% straw. However, the percentages on an as-is basis are dependent on the DM or moisture content of both the straw and the WDGS. Grass hay is less fibrous than either wheat straw or corn stalks and, as a result, more grass hay is needed when mixed with WDGS. Our recommendation for combining grass hay and WDGS is to mix 15% (only 6-6.5% on an as-is basis) grass hay with 85% WDGS. Bags did split when the 7.5% and 10% grass hay mixtures were used. More alfalfa is required than any other forage tested. However, alfalfa is an unlikely forage source to be used due to cost and quality. If alfalfa was used, then the appropriate mixture would be 22.5% alfalfa with 78.5% WDGS (DM basis). Based on our studies, Table 1 provides the minimum mixtures required for grass hay, alfalfa hay, wheat straw, DDGS and WCGF when combined with WDGS.

We would recommend lower quality forages such as low-quality hays, straws or stalks, as they require lower amounts to be mixed with WDGS, are usually less expensive, and may be a good use for these low-

Table 1. Example calculations for converting from a mixture of two feeds on a DM basis to an as-is basis. The percentages on an as-is basis are required for actually weighing the feeds into your mixer. The percentages on a DM basis were the minimal amounts required of these different feeds to store in bags under pressure.

Column:	A	B	C	D	E
Equation:			=(B÷C)	=(C÷total of C)	=(total B÷total C)
	Ingredient DM, %	% of mix (DM basis)	Parts as-is = % of mix/ ingredient DM	% of mix (as-is basis)	Final DM of mix, %
Grass	90.00%	15.0%	16.7	6.2%	37.5%
WDGS	34.00%	85.0%	250.0	93.8%	
Total		100.0%	266.7	100.0%	
Alfalfa	90.00%	22.5%	25.0	9.9%	39.5%
WDGS	34.00%	77.5%	227.9	90.1%	
Total		100.0%	252.9	100.0%	
Straw	90.00%	12.5%	13. 9	5.1%	36.9%
WDGS	34.00%	87.5%	257.3	94.9%	
Total		100.0%	271.2	100.0%	
DDGS	90.00%	50.0%	55. 5	27.4%	49.4%
WDGS	34.00%	50.0%	147. 1	72.6%	
Total		100.0%	202.6	100.0%	
WCGF	44.00%	60.0%	136.4	53.7%	39.4%
WDGS	34.00%	40.0%	117.6	46.3%	
Total		100.0%	254.0	100.0%	

quality forages compared to high-quality forage. In many cases, this "mixture" of forage and WDGS may serve as the entire roughage source for feedlots to use in their finishing rations.

It is not clear whether mixing low-quality forages with WDGS actually improves the palatability and/or digestibility of the forage when fed to cattle. To test this, we have conducted feeding experiments and are in the process of comparing "stored" forage and WDGS combinations compared to feeding a similar mixture of WDGS and forages "fresh" daily.

For cow-calf producers that want to combine low-quality forages with WDGS to maintain a herd or to enhance the low-quality forage, perhaps determining the minimum amount of forage needed to bag WDGS is not the goal. In their situation, increasing the amount of forage may be more beneficial if it allows for storage of low quality forages and a mechanism to feed these forages to beef cows or growing cattle.

We have bagged mixtures of 67% wheat straw with 33% WDGS, 33% wheat straw with 67% WDGS, and a 50:50 blend of corn stalks and WDGS (DM basis). We have also stored a mixture of 56% grass hay with 44% WDGS in a Nebraska Sandhills ranch setting (Figure 6). The WDGS was dumped on the ground in a meadow and was easily picked up by equipment. In all cases, storage was possible and little to no spoilage was visually observed. However, with greater amounts of dry, low-quality forage, one challenge may be insufficient moisture to allow for compaction in the bag and to exclude all the air. If the mixture is too dry, then some air may be "trapped" even in a bag that was compacted under pressure. It is not clear what minimum amount of moisture is required to ensure enough moisture to adequately compact the mixture in the bag and/or prevent spoilage.

More recently, we have bagged 25% solubles with 75% wheat straw, but increased the moisture (or decreased the DM) to 50%. Similar storage worked well with 45% solubles and 55% straw, 25% WDGS with 75% straw, and 55% WDGS with 45% straw (DM basis). The solubles at either 25% or 45% and the WDGS at 25% mixtures were all increased to 50% moisture by adding water (or decreased to 50% DM) and stored in a bag with no spoilage or compacting problems observed. We would estimate that mixtures of less than 35-40% moisture are more risky in terms of spoilage during storage in a bag. This risk is likely greater in bunker storage facilities, as will be discussed, compared to bags.

Bunker Storage

While storing straight WDGS or adding forage with WDGS and storing in bags may fit for many producers, others have wanted to bring in quantities that make bagging difficult, or the producers may have a bunker to store feed. Storing WDGS in bunkers is somewhat different than in bags. However, the concept is still the same in terms of adding feeds to WDGS to ensure that when the mixture is packed into the bunker that air is excluded. The amount of forages needed has been evaluated and many producers have adopted this practice successfully.

We initially mixed 30% grass hay with 70% WDGS (DM basis) and packed with a skid loader with rubber tracks. This mixture worked fine and compacted; however, the weight of a pay loader was not maintained on the pile. A bunker with 40% grass hay with 60% WDGS (DM basis) did compact in the bunker and yet maintained the weight of a pay loader (Figure 7). Similar to bagging, forage sources can likely be exchanged on an equal fiber (i.e., NDF) basis. For example, 29% corn stalks was successfully stored with 71% WDGS in a

Figure 6. WDGS piled on a meadow in the Nebraska Sandhills, and mixed with 56% grass hay (DM basis) using a vertical mixer that bales were loaded directly into. Storage worked well and the mixture was supplemented to grazing cows.

Figure 7. Initial bunker tests with 70% WDGS and 30% grass hay (on the right) and 60% WDGS and 40% grass (on the left). Mixtures are on a DM basis.

Figure 8. Cow-calf producer with a mixture of 20% wheat straw and 80% WDGS (as-is basis), which is 38-40% wheat straw on a DM basis.

Figure 9. Same producer with a similar mixture as Figure 8 from the second year. The mixture was 20% wheat straw and 80% WDGS (as-is basis), which is 38-40% straw on a DM basis.

bunker with little spoilage. In this example, dry cows were fed this mixture in a dry lot situation.

Many producers have made mixtures and packed them into bunkers. In some cases, these producers "made" bunkers with round bales or other less permanent structures. In all cases that we are aware of, producers had good experiences, were satisfied with their storage, and many have continued to store WDGS across multiple years. Many producers have recorded what the mixtures were on an as-is basis, and not always on a DM basis. We can make some estimates of the mixtures on a DM basis by using assumed moisture contents of the different feeds. When possible, we will report what is known (as-is percentages) and approximate the mixtures on a DM basis.

Figure 8 and Figure 9 are a mixture of WDGS and wheat straw from a cow-calf producer near Kearney,

Figure 10. Grass hay and modified WDGS (45% DM) mixed in a bunker made of round bales, covered in plastic and ground hay. Mixture is 15% grass hay and 85% modified WDGS (DM basis).

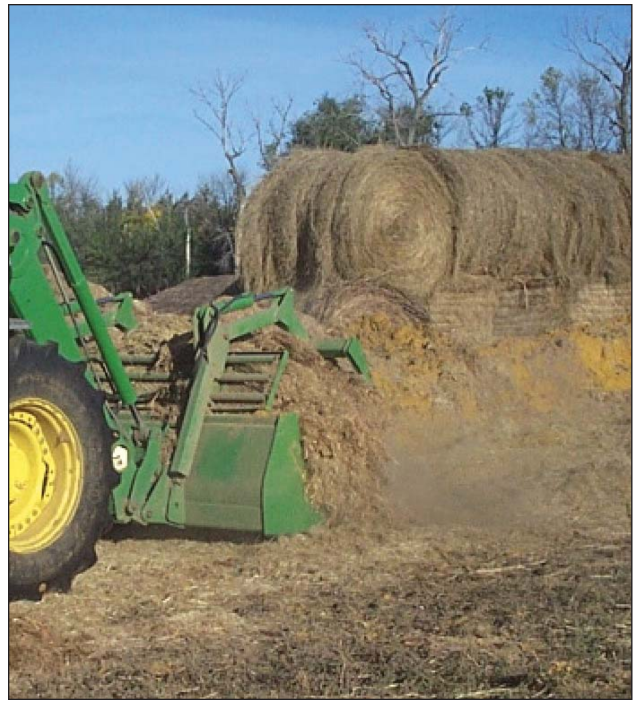

Figure 11. Mixing of grass hay and modified WDGS at a ranch using a front-end loader. The modified WDGS was unloaded on the ground with hay in layers and pushed together with a front-end loader. For cow-calf producers, this may be mixed enough to ensure proper storage and still be adequately mixed for feeding.

Neb. The mixtures used were 20% wheat straw and 80% WDGS (as-is basis) for both years. Assuming the WDGS is 35% DM and the wheat straw is 90% DM, this equates to approximately a ratio of 39% wheat straw and 61% WDGS on a DM basis. In year 1 (Figure 8), the pile was covered and bales were used for sides. In year 2 (Figure 9), the pile was larger and, again, covered in plastic with bales used for sides.

Modified WDGS is a dryer product than traditional WDGS. Therefore, less forage may be needed to adequately pack into a bunker. Figure 10 illustrates a mix of 15% grass hay and 85% MWDGS put into a bunker with round bales as sides. In many situations, mixing of the forage with WDGS is one of the biggest challenges.

First, the forages need to be ground or at least a sufficient particle size to adequately mix with WDGS. Often, producers may want to mix the forage and WDGS (or MWDGS) in a mixer that is used for feeding. However, if ranchers or producers do not have equipment for mixing, then mixing equipment can be rented or purchased or another system of mixing may be used. In Figure 11, this same producer that used MWDGS and grass hay used a front loader to mix the forage and MWDGS together during the packing process. Having an accurate mix with a known and consistent amount of forage may be more critical for feedlots than in many cow-calf situations. This method of mixing seemed to work fine for this producer. However, caution is required to ensure that there are no pockets of air due to inadequate mixing of forage and WDGS (or MWDGS) to ensure that spoilage does not occur. The same caution is required if particle size of the forage is not small enough to mix well with the WDGS.

Figure 12. Concrete bunker with 85% WDGS and 15% wheat straw (as-is). The straw was ground through a 1-in. screen. In the foreground is straight WDGS being fed fresh. The bunker contains 9,000 tons of WDGS all mixed through vertical mixers.

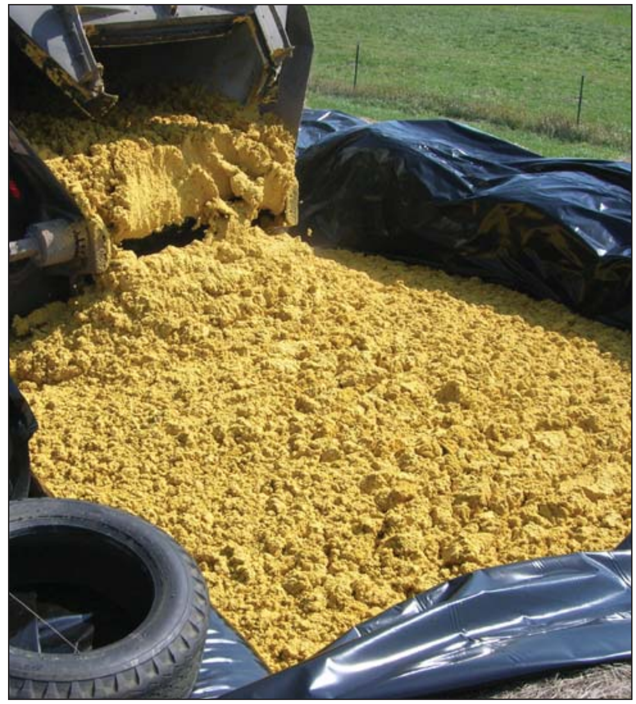

Figure 13. Piling WDGS (30-35% DM) and covering in a bunker made of round bales.

Figure 14. WDGS piled and covered in the same bunker as Figure 13.

Figure 15. WDGS piled and covered in the same bunker as Figure 13 illustrating a small layer of spoilage across the surface, but little change within the pile.

For many producers, the task of mixing and storing WDGS or MWDGS may seem daunting. However, large quantities of WDGS can be stored and in a relatively short period of time if the WDGS can be procured. For example, in Figure 12, a Nebraska feedlot stored 9,000 tons at two separate locations in a concrete bunker. In this case, the producer was mixing everything through vertical mixers and was able to put up to 35 semi-loads of WDGS in the bunker a day for multiple days. The mixture used was 15% wheat straw (1-in. grind) and 85% WDGS (as-is basis). This equates to approximately 30% wheat straw and 70% WDGS on a DM basis, assuming that WDGS is 65% moisture (35% DM) and wheat straw is 90% DM.

One of the challenges with traditional WDGS (30-35% DM) is that it will not pile or allow for producers to make a bunker of straight WDGS with no added forage. Once the WDGS is piled, it tends to "flow" some and spread resulting in piles that are very wide, yet very short in height. For storage of relatively small quantities (1 semi-load of 30 tons or less), then storage may be accomplished by unloading WDGS directly onto plastic (Figure 13) and covering just after unloading (Figure 14). As illustrated in the picture, the piles are unable to be compacted with equipment, but spoilage is likely minimized. Figure 15 illustrates that some spoilage occurs on the surface, but little observed below the surface when piles are covered.

Modified WDGS that is 42-50% DM and WCGF that is either 45% or 60% DM does pile and may be stored in a bunker by itself without forage added. However, the pile cannot be compacted by driving equipment onto the feed in a bunker. There are numerous examples of producers that have piled and covered either WCGF or MWDGS and had little spoilage (except on the top surface as would be expected). In Figure 16, piling of MWDGS appears to work in either earthen bunkers or concrete bunkers. We would always recommend covering with plastic or some mechanism to minimize spoilage at the surface. This storage method of just piling either MWDGS or WCGF is "riskier" in terms of spoilage

Figure 16. Piling modified WDGS (42-50% DM) straight in a bunker.

losses, but has been done at least commercially. If plants do not add solubles (corn syrup) back onto wet distillers grains to make WDGS, often times the WDG (without solubles) may pile easier than if solubles are added back to the wet grains. In Figure 17, a producer has piled WDG (without solubles) and covered the surface with stock salt (1 lb. per square foot at the surface) and plastic. The pile did not spoil and was fed throughout the winter following storage.

Solubles Mixed with Forage

Distillers solubles (condensed corn distillers solubles or corn syrup) is a liquid feed product that is readily available and usually inexpensive relative to nutrient composition. Solubles are normally 25-35% DM and contain more fat, but somewhat less protein than WDGS. The challenge with distillers solubles is that you must have storage and unloading facilities to handle liquid feeds. In most cases, storage equipment is sized

Figure 17. WDG (without solubles) stored straight in a bunker lined with plastic and round bales. The pile was treated on the surface with 1 lb. of stock salt per square foot then covered in plastic.

to handle 1 or 2 semi-loads. Therefore, purchasing large quantities (much more than 2 semi-loads) may not be feasible if the solubles are handled as a liquid. Handling distillers solubles brings challenges inherit in all liquid feeds such as equipment and pumps, circulation of the liquid to ensure that "settling" does not occur or separation and the potential for freezing in cold temperatures. Therefore, one option that may be possible is to store distillers solubles mixed with forages in either bags or bunkers. This may allow producers to purchase large quantities and store them for later use, regardless of temperature.

Solubles have been stored in both bags and in bunker storage facilities. The concept is similar to storage of WDGS, except more forage is generally needed. We have stored mixtures of 41% solubles with 59% corn stalks (ground through a 7-in. screen) in a bunker. The DM content of the stalks is important, as is the grind size. It appears that approximately 50% stalks or wheat straw would be the minimum required to successfully store solubles in a bunker. Assuming solubles are 30% DM and forage is 90% DM, then a 50:50 blend of solubles and forage on a DM basis equates to 75% solubles and 25% forage on an as-is basis. It is important to measure the moisture (i.e., DM) content of both the solubles and the forage.

Bagging solubles mixed with forage is likely less risky in terms of spoilage than bunker storage. Storing solubles in bags has been accomplished by mixing 50% corn stalks with 50% solubles (DM basis), and 50% solubles with 50% wheat straw. More recently, we have bagged 25% solubles with 75% wheat straw but increased the moisture (or decreased the DM) to 50%. Similar storage worked well with 45% solubles and 55% straw (DM basis). The solubles at either 25% or 45% mixed with straw was increased to 50% moisture (or decreased to 50% DM) by adding water and stored in a bag with no spoilage or compacting problems observed. Spoilage may be a larger concern with solubles than with WDGS, but does not appear to be a challenge to bag.

Costs and Spoilage Losses

Costs of storage in either a bag or bunker are difficult to estimate. Many factors need to be addressed. In Table 2, a cost budget is shown that can assist producers in estimating the cost of storing WDGS (or other co-products). A cost budget analysis spreadsheet is also available for download at beef.unl.edu under the "byproduct feeds" tab.

Using an example of purchasing WDGS at a cost of $30/ton (as-is) at a DM percentage of 34%, the cost of mixing 15% wheat straw with 85% WDGS on an as-is basis and storing it for 150 days is calculated. The costs of the wheat straw, WDGS and the DM and as-is quantities of each are needed in this cost budget and are shown at the top of Table 2. Similarly, estimates of labor, equipment costs, interest, and shrink are required to make appropriate estimates of costs. While these costs can be difficult to estimate, the spreadsheet on the website can assist in these calculations. Ultimately, the cost of storage has to be evaluated on a dollars-per-ton as-is basis and DM basis to make fair comparisons to alternative stored and purchased feeds. The economic costs of storage can add up, thereby making these calculations critical for producers to make sound decisions on whether to store wet co-products for feeding at a later date.

Shrink or spoilage losses are likely lower for bagging compared to bunker storage; however, few data are available to make this comparison. Spoilage losses measured as DM weight put into the bag versus DM weight removed from the bag likely vary from 2% to 15% with a few examples measured from 8% to 12%. Shrink is challenging to measure and will vary among different operations depending on storage method, compaction and likely particle size of the forage. In many cases, producers are willing to risk shrink due to the cost of the co-product relative to other feed ingredients. It is prudent to assume 10-15% shrink in the absence of measurements on your own operation and to include these in your cost estimates of storage. Another approach is to assume that storage losses will be similar to silage storage, which is 3-6% for bags and 10-14% for covered bunker storage facilities.

Mold production and foul odor may occur during storage of wet co-products, especially when piled and left uncovered. Figure 18 illustrates piling WDGS on the ground with no cover. After weeks of storage, some color change is noted (Figure 19) as well as some mold growth at the surface (Figure 20). If the pile "seals" itself, the material below the suface may be good quality. Our experience is that the amount of mold is directly proportional to the oxygen permeability of the plastic covering the storage site, with thicker plastics resulting in less visible mold. Given concerns over the dangers of feeding moldy corn grain to livestock one might reasonably question the safety of feeding moldy coproduct to livestock.

As part of our efforts to evaluate different storage techniques, we have analyzed samples from four different storage sites for mycotoxin concentrations. Each sample was safe in terms of mycotoxins. We tested for the presence of aflatoxins, ochratoxins, vomitoxin, zeralenol, zearalenone, T-2 toxin and fumonisin – all the major mycotoxins found in grains and potentially grain byproduct feeds. Only fumonisin was found to be present in any of the samples – but at a low level. The site with the greatest concentration of fumonisin was 1.4 ppm, with the average in all four samples being 0.8 ppm. The Food & Drug Administration recommends total fumonisins in rations not exceed 30 ppm. Thus, the levels of fumonisins observed in our stored piles are considered safe. For comparison, the FDA considers 3 ppm the safe threshold for human foods. Because the fresh distillers were not tested, it is not possible to determine whether the fumonisins were produced during storage or whether they were present in the corn grain before entering the ethanol plant and were in WDGS prior to storage. The bottom line from our experience is that mycotoxins are a minimal concern at least based on limited data thus far.

Storage of Wet Corn Co-Products

Table 2. Approach for determining a cost budget for storage of wet co-products and example calculations for 200 ton of WDGS stored with straw at a mixture of 85% WDGS and 15% straw on an as-is basis.

	Example	Operation
Inputs		
1. *Co-product cost ($/ton as-is)	$ 30.00/ton	$
2. *DM of co-product	34.00%	
3. *Tons of co-product (as-is)	200.00 ton	
4. Co-product cost, ($/ton DM) (#1 ÷ #2)	$ 88.24/ton	$
5. Tons of co-product (DM tons) (#2 x #3)	68.00 ton	
6. *Bulking agent cost, wheat/oat straw, etc. ($/ton as-is)	$ 45.00/ton	$
7. *DM of bulking agent	88.00%	
8. *Tons of bulking agent used (as-is)	35.30 ton	
9. Tons of bulking agent used (DM tons) (#7 x #8)	31.10 ton	
10. Total tonnage of feed (As-is basis) (#3 + #8)	235.30	
11. Total tonnage of feed (DM basis) (#5 + #9)	99.10	
12. Final DM % of mixture (#11 ÷ #10)	42.12%	
* required inputs from producer		
Feed Costs		
A. Total cost of co-product at the plant (#1 x #3)	$ 6,000.00	$
B. Cost of bulking agent(s) (#6 x #8)	$ 1,588.50	$
C. Total feed cost (A + B)	$ 7,588.50	$
Non-Feed Costs		
D. Transportation from plant • (Miles hauled x cost/mile) x # of loads; (25-28 ton DM/load typically) • Example: $4/loaded mile, 30 miles, 8 loads	$ 960.00	$
E. Labor ($/hour x Hours Worked) • Example: $10/hour for 12 hours	$ 120.00	$
F. Fuel ($/gallon x gallons used) • Example: $4/gallon x 60 gallons x 2 pieces of equipment)	$ 480.00	$
G1. Cost of Bunker • Round bales, concrete, etc. • Example: 20 round bales x $25/bale	$ 500.00	$
G2. Cost of Bagging	$ NA (bunker)	$
H. Other Equipment Rental ($/hour x Hours) • Include rental rate for owned equipment as an opportunity cost (not in G1 or G2) • Example: $30/hour for 12 hours x 2 pieces of equipment	$ 720.00	$
I. Miscellaneous Costs • Plastic, tires, etc.	$ 90.00	$
J. Total Non-Feed Costs (D + E + F + G1 + G2 + H + I)	$ 2,870.00	$
K. Interest Costs ([C + J] x Interest Rate/yr x Days stored/365) • Example: ((7588.50 + 2870.00) x 0.08 x (150 ÷ 365)) for 8% interest and 150 days of storage	$ 343.84	$
L. Total Costs (C + J + K)	$ 10,802.34	$
M. Tons left to feed after shrink (as-is) (#10 – [#10 x % Shrink]) • (Best to measure shrink in your own operation, but we recommend 3-6% for bagging and 8-15% in bunker storage. For this example, we used 10% shrink)	211.80 ton	
N. Tons left to feed after shrink (DM) (M x #12) • Key assumption: DM percentage was unchanged. We recommend sampling and testing for moisture.	89.20 ton	
O. Feed cost ($/ton as-is) (L ÷ M)	$ 51.00/ton	$
P. Feed cost ($/ton DM) (L ÷ N)	$ 121.10/ton	$

Figure 18. Piling WDGS on the ground and storing with no cover or bunkers.

Feeding Performance of Cattle Fed Stored WDGS

All of the stored material has been fed to cattle without problems. However, five experiments were designed to test the stored mixtures when fed to cattle at the University of Nebraska. The first experiment (Exp. 1) compared feeding WDGS mixed with 35% grass hay and stored in a bunker (average of the 30% and 40% grass hay mixtures with WDGS as they were combined during feeding). The mixture was limit-fed to cows compared to feeding more traditional forage diets ad libitum. No problems were observed.

In year two (Exp. 2), 70 non-lactating, non-pregnant beef cows (1,303 + 139 lb.) were used to evaluate the performance of limit-fed diets containing either bunkered WDGS or bunkered distillers solubles compared to a forage-based control diet (Kovarik et al., 2008). Pens (3 per treatment) were assigned randomly to treatment. Wet DGS and solubles were stored in a bunker with ground (7-in. screen) corn stalks 30 days prior to the start of the trial. Solubles were mixed with 59% corn stalks (41% solubles) while WDGS were stored in combination with 30% corn stalks (DM basis). Diets were fed for 76 days and formulated to maintain cow bodyweight (BW). The WDGS diet contained 41% WDGS and 59% corn stalks with intake limited to 17 lb./day. Corn stalks were added to the "mixed" material for diets to contain 59% total stalks. The distillers solubles diet contained 41% distillers solubles and 59% corn stalks with intake limited to 17 lb./day. The control diet contained 43% bromegrass hay, 34% corn stalks and 23% alfalfa haylage and fed ad libitum (22.8 lb./day intake). Average daily gain (ADG) tended ($P=0.09$) to be greater for WDGS (0.82 lb./day) treatment compared to the control treatment (0.44 lb./day) with cows limit fed the solubles mix being intermediate (0.68 lb./day). These data suggest that cows limit fed a diet of either WDGS or solubles stored in a bunker with ground corn stalks has no negative impacts on performance compared to more traditional, ad-libitum fed forage diets.

Two growing experiments (Exp. 3 and Exp. 4) were conducted to evaluate WDGS mixed and stored with wheat straw (Nuttleman et al., 2008). In Exp. 3, 93 crossbred steer calves were individually fed to evaluate

Figure 19. Similar piles of WDGS following a few months of storage while exposed at the surface.

Figure 20. Piled and stored WDGS illustrating drying out at the surface and mold growth on the top few inches.

performance between DDGS, WDGS and a 67% WDGS and 33% ground wheat straw mixture (DM basis) stored in bags for 30 days prior to initiation of the trial. Steers were supplemented one of four levels of co-product: 0.0, 2.0, 4.0 or 6.0 lb. of distillers grains daily. The base diet consisted of 60% sorghum silage and 40% alfalfa hay with supplement top-dressed. Gain increased linearly with increasing levels of co-product supplementation (1.52 to 2.62 lb./day). Steers supplemented the mixture had lower dry matter intake (DMI) compared to DDGS and WDGS (P=0.05) because of the straw; however, feed conversion was not reduced. In Exp. 4, 96 steers were used to determine palatability of WDGS mixed with wheat straw. Steers were fed either 50% WDGS and 50% wheat straw mix, or 60% WDGS and 40% wheat straw mix. A base diet containing 60% sorghum silage and 40% alfalfa hay was also fed either simultaneously or a minimum of four hours post feeding the assigned level of WDGS and wheat straw mix. Calves fed 60% WDGS gained more than calves fed 50% WDGS (2.2 vs. 2.0 lb./day). Time of feeding had no effect on percent of forage consumed; however, the lower level of WDGS tended to increase forage intake. Data from both trials suggest that mixes of WDGS and straw from 33% to 67% will store, be palatable and reduce intake of forage that is equivalent in quality to grazed forage.

In Exp. 5, 120 individually fed growing steers (bodyweight = 314 ± 21 kg) were used to compare distillers solubles to WDGS when mixed and stored with corn stalks (Wilken et al., 2008). In addition, the effect of feeding stored WDGS and stalks was compared to feeding the same mixture of WDGS and stalks fresh daily. The co-products and stalks were mixed and bagged in a 50:50 ratio (DM basis) and fed to provide co-product level in the diet of 15, 20, 25 and 30% DM. The co-product and stalks mixture replaced grass hay in the diet and was mixed at the time of feeding. A 2 x 4 factorial treatment design was used with factors of co-product type (solubles and WDGS) fed at 4 levels (15, 20, 25 or 30%). An additional treatment was included where 30% WDGS and 30% stalks were fed fresh daily to compare performance of stored (ensiled) versus non-ensiled WDGS and stalks. Steers fed increasing levels of either solubles or WDGS resulted in a linear increase in ADG and improvement in feed conversion. Calves fed solubles gained less (1.03 vs. 1.26 lb./day) and had greater feed conversion (feed:gain; 15.6 vs. 12.5) compared to calves fed WDGS diets when averaged across all levels of supplementation in this study. When calves were fed 30% WDGS and 30% stalks that were mixed fresh daily (non-ensiled), calves had lower DMI (12.1 lb./day), ADG (1.01 lb./day) and poorer feed:gain (11.9) than calves fed stored (ensiled) WDGS with stalks (14.1, 1.43 and 9.8, for DMI, ADG and feed:gain, respectively). Feeding ensiled solubles or WDGS mixed with stalks improve performance of backgrounding calves fed grass hay. It appears that ensiling WDGS with stalks results in better feeding values than solubles stored with stalks. Likewise, storing WDGS with stalks appears to yield equal or better feeding values than mixing fresh daily, as DMI and ADG were improved in this study.

Conclusions

This information will hopefully be a useful starting point for producers that want to take advantage of storing co-products. Storage offers flexibility for small producers to use wet co-products, cow-calf producers that want to purchase wet co-products during summer months for use later, and for large feedlots that may be able to store large quantities. For storage in bags under pressure, less forage is needed as compared to bunker storage. Inexpensive, low quality forages are likely the best choice and the feeding value may be improved compared to feeding the same mixture fresh daily. Producers may need to make adjustments as they store WDGS to make it work within their operations. However, if air is excluded, there are likely many different combinations that producers can use to effectively store wet co-products. More information is needed on both costs and shrink or spoilage losses.

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