Economics Associated with the Storage of Ethanol Co-Products for the Purpose of Inclusion in Cattle Rations

A User Instruction Manual for Co-Product STORE:
Co-Product Storage To Optimize Ration Expenses

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Introduction

The rapid growth of the ethanol industry in recent years has led to the development of a new commodity market for ethanol co-products. The variability in co-product prices over time and across markets suggests fundamental supply and demand factors are influencing prices. However, the relative infancy of these co-product markets presents cattle producers with the opportunity to benefit from seasonal price changes. Until recently, there was no means in which to arbitrage temporal price differences in co-product prices because storage was not considered feasible. In the past two years, there has been a substantial amount of research devoted to methods of co-product storage (Erickson et al., 2008). Thus, livestock producers can now take advantage of seasonal price changes in co-products, similar to purchasing and storing grain.

Although much research has been conducted exploring methods to store co-products and the effects of co-product feeding on cattle performance (Erickson et al., 2007), little has been done in evaluating the economics of storing co-products for extended periods of time. The following discussion will address the potential opportunities to store co-products and will describe a user-friendly Excel spreadsheet called Co-Product STORE (Storage To Optimize Ration Expenses) that is designed to analyze the costs associated with different co-product storage methods for the purpose of co-product inclusion in cattle rations.

Opportunity for Ethanol Co-Product Storage

Although the ethanol co-product market is an emerging market to some extent, much research has been conducted regarding cattle performance in response to co-product feeding, both from the aspect of feedlot and cow/calf operations. Research has shown that feed conversion, average daily gain, and final body weight all increased for feedlot cattle consuming co-products as compared to cattle consuming a control diet containing no co-product (Buckner et al., 2007). Birth and weaning weights of calves from heifers as well as heifer body condition were found to improve with dried distillers grains plus solubles (DDGS) supplementation as compared to a standard system used by ranchers when wintering pregnant heifers (Stalker, Adams, and Klopfenstein, 2006). Forage intakes have been shown to decrease linearly with increased supplementation of co-products for yearling steers grazing range (Morris et al., 2006). A similar study involving calves grazing corn residue also showed decreased forage intake when supplemented with DDGS (Gustad et al., 2006), which might suggest the potential for economic benefits due to more forage availability or increased stocking rates.
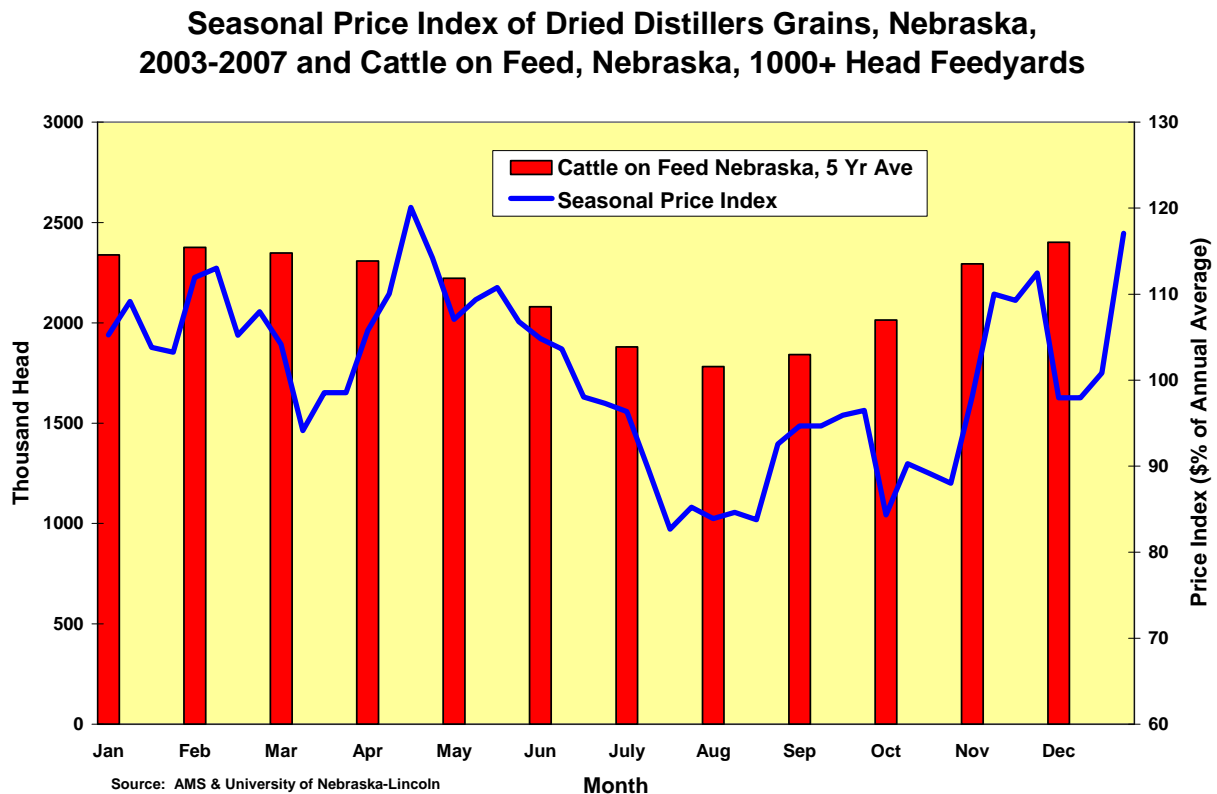
These previously described studies indicate that ethanol co-products, particularly wet distillers grains plus solubles (WDGS), are an excellent feedstuff for feedlot cattle as well as a great supplement for cows or calves on forage. Further, analysis of the costs and benefits of feeding WDGS and other co-products indicate that it is profit-enhancing as well. For example, Buckner et al. (2008) showed that the marginal returns to cattle feeding improved by $30 to $50 per head when fed WDGS at 30 to 40 percent of the ration on a dry matter basis. Stalker, Adams, and Klopfenstein (2006) found a $10 per head advantage to wintering pregnant heifers that were fed co-product.

While existing research shows both physiological and economic improvements resulting from co-product feeding, little research has been completed evaluating the

economics of storing ethanol co-products. Some evidence based on relatively short time periods does support the observation that co-product prices follow a similar yearly trend to that of the number of cattle on feed, particularly in Nebraska. Figure 1 shows the seasonal price index for DDGS in Nebraska and the 2003-2007 average of the number of cattle on feed in Nebraska (Waterbury and Mark, 2008). As the graph illustrates, DDGS is priced seasonally lowest during the summer months, and although only DDGS is represented in Figure 1, the seasonal price trend can generally be applied to any ethanol co-product, including WDGS and modified wet distillers grains plus solubles (MWDGS), although data limitations to illustrate these exist. Because co-product supply does not vary dramatically within a given year, the seasonal low price is largely driven by the

number of cattle on feed during the associated time period. When cattle on feed inventory is high, feed demand for co-products is high. As shown in Figure 1, the number of cattle on feed is also seasonally lowest during July, August, and September. As a result, ethanol co-product prices are relatively constant throughout the fall, winter, and spring, and significantly decrease throughout the months of July and August when cattle on feed inventory declines. This decrease in co-product price during the late summer months provides incentive for producers to purchase co-products during this period when they are usually cheapest. Producers can then store the co-product and feed it at a later date. This is particularly convenient for many cow-calf operations and smaller feedlots that are unable to utilize an entire truck-load of co-product at one time. Furthermore,

Figure 1

Seasonal Price Index of Dried Distillers Grains, Nebraska, 2003-2007 and Cattle on Feed, Nebraska, 1000+ Head Feedyards

smaller operations are limited in their ability to efficiently use WDGS because feeding rates are often too low to avoid spoilage (Adams, Klopfenstein, and Erickson, 2006). Storage of ethanol co-products would allow small operations to utilize the feedstuff more efficiently as well as provide incentive for any type of operation to purchase co-products when prices are seasonally lowest.

Storing co-products is also a natural procurement and price hedge. By physically owning the commodity, cattle feeders and ranchers are somewhat protected against the risk of being able to obtain the co-product (or any feedstuff) at any price level. As corn supplies become increasingly tight and demand for co-products grows, this is a risk to be concerned about. Further, storing purchased co-product is a price hedge in that higher spot prices for co-products will not affect the producer feeding stored co-product.

Methods of Co-Product Storage

In the past couple years, several methods of ethanol co-product storage, particularly for WDGS, have been investigated by University of Nebraska–Lincoln researchers and cattle producers (Erickson et al., 2008). Previous research has established that WDGS will not spoil over an extended period of time (usually greater than two weeks in the summer and four weeks in the

spring, fall, and winter) if oxygen is eliminated. Because WDGS contains high levels of moisture (generally 35 percent dry matter), it was previously thought that this co-product could not be stored in a bunker silo or be packed. Furthermore, WDGS itself does not store well in silo bags because pressure cannot be easily and efficiently applied (Adams, Klopfenstein, and Erickson, 2006).

Based on the evaluation of WDGS mixed with dry forages, dry co-products, and dry grain, Erickson et al. (2008) have concluded that adding minimal amounts of relatively inexpensive dry, bulky feedstuffs to WDGS may solve the previously described challenges associated with the storage of WDGS in silo bags and/or bunkers. Table 1 shows the recommended feedstuffs that should be mixed with WDGS in a silo bag or bunker as well as the appropriate levels of inclusion (see Erickson et al., 2008, for more information). Bunker storage includes cement bunkers or pads as well as home-made bunkers using large round hay bales or other equipment. These same concepts apply to DDGS and MWDGS storage, although these co-products usually do not have to be mixed with another feedstuff as spoilage is less of an issue due to lower moisture contents and it is easier to pack a drier product. In any case, it may be beneficial for any ethanol co-products placed in storage to be covered with plastic

Table 1: Mixture Inclusion Levels for Storing Wet Distillers Grains plus Solubles

Feedstuff	Silo Bag* (%, DM Basis)	Bunker (%, DM Basis)
Grass Hay	15	30-40
Wheat Straw	12.5	25-32
Alfalfa Hay	22.5	45-55
DDGS	50	--
ADM Corn Gluten Feed	60	--
*300 psi		

or some other type of protective material in order to reduce costs associated with shrink and/or spoilage.

Ethanol Co-Product Storage Spreadsheet: Co-Product STORE

Cattle feeders and cow/calf producers must analyze several factors to make a decision regarding the purchase and storage of ethanol co-products. Storing the co-product must be economically and physically feasible. The cost of the co-product and storage materials and procedures must not exceed the benefits of actually storing the co-product (the total storage cost must be cheaper than that paid for the co-product at a later time without storage). Producers must also recognize and define the type of storage method that is optimal for their own operation. Co-Product STORE (Storage To Optimize Ration Expenses) is designed to help producers analyze and address these issues.

Co-Product STORE, which is available at the UNL Beef Website (beef.unl.edu; click on "By-product Feeds" tab), is organized into four steps. It allows users to define costs and include parameters that are more representative of their own individual operation. All cells outlined in blue can be changed by users and will appear as "blue" text, while calculated costs and outputs appear as "red" text. A results summary is included at the top of the spreadsheet that summarizes total costs, total mixture and shrink costs per ton, co-product costs per ton, and feed tonnage. The tab entitled "Storage Budget General" is a blank budget that individuals should use to input costs and parameters, while the tabs entitled "Bunker Example" and "Bag Example" illustrate a bunker example and silo bag example, respectively. Steps One through Four and the Results Summary are outlined below.

Step 1: Parameters (Green-colored Box)

- **Interest Rate on Feed and Supplies:** The rate of interest that must be paid to borrow money in order to purchase feed and supplies should be entered in Cell J4. If a producer's own money is being used (no money is being borrowed), the interest rate is the opportunity cost of investing that money in alternative investments, so interest costs should still be included.
- **Shrink:** The amount that the initial co-product(s)/mixture placed in storage differs from the amount actually fed should be entered in Cell J5. For example, if 100 tons of feed were placed in a bunker and 95 tons of feed were actually fed, a five percent shrink would be associated with that particular storage situation ((95-100) / 100 = 0.05). Shrink will vary depending upon which storage method is used, the type of feedstuff used (both forage and co-product), the type of surface the mixture is placed on, the length and time of year for the storage period, the size of the storage pile and surface area, and whether the mixture is covered or not. Shrink or spoilage losses are likely lower for bagging compared to bunker storage. Although shrink should be measured for each individual operation, a conservative shrink recommendation may be one percent shrink per week, up to a maximum of 15 percent shrink for the entire storage period. Another approach is to assume that storage losses will be similar to silage storage, which is three to six percent for bags and 10 to 14 percent for covered bunker storage facilities (see Erickson et al., 2008, for more details).
- **Tons of Co-Product per Loaded Truck:** The tons of co-product hauled by one semi-truck to the site of storage should be entered in Cell J6. The capacity of one semi-truck hauling ethanol co-product is generally 25 tons (50,000 pounds), although this number may vary from truck to truck.

- **Date Co-Product Placed in Storage:** The date the co-product is placed in storage should be entered in Cell J7. Enter the date in MM/DD/YYYY format.
- **Date Start Feeding Stored Co-Product:** The date the operation expects to start feeding the stored co-product should be entered in Cell J8. Enter the date in MM/DD/YYYY format.
- **Date Finish Feeding Stored Co-Product:** The date the operation expects to finish feeding the stored co-product should be entered in Cell J9. Enter the date in MM/DD/YYYY format.
- **Days of Storage Before Feeding:** This value is automatically calculated and is the difference between Cell J8 (Date Start Feeding Stored Co-Product) and Cell J7 (Date Co-Product Placed in Storage). This calculation helps to allocate the appropriate interest cost of the stored feed across the storage period.
- **Days of Storage During Feeding:** This value is automatically calculated and is the difference between Cell J9 (Date Finish Feeding Stored Co-Product) and Cell J8 (Date Start Feeding Stored Co-Product). This calculation helps to allocate the appropriate interest cost of the stored feed across the storage/feeding period.
- **Total Days of Storage:** This value is automatically calculated and is the difference between Cell J9 (Date Finish Feeding Stored Co-Product) and Cell J7 (Date Co-Product Placed in Storage).

Step 2: Feed Costs (Aqua-colored Box)

- **Ethanol Co-Products and Forages:** A list of possible co-products (wet distillers grains plus solubles, dry distillers grains plus solubles, modified wet distillers grains plus solubles, wet corn gluten feed, dry corn gluten feed, Sweet Bran®, and Dakota Bran™ Cake) as well as forages (wheat straw, cornstalks, grass hay, and alfalfa hay)

are included in this section. More than one co-product and/or more than one forage may be included in the storage mixture in the spreadsheet. If the co-product being used is not listed, place the co-product name in Cells D31 and/or D32. If the forage used is not listed, place the forage name in Cells D39 and/or D40. Then, for all the co-products and/or forage (including those added), enter the dry matter percent, percent crude protein (dry matter basis), percent total digestible nutrients (dry matter basis), tons used (as-is basis), and price per ton (as-is basis) in the appropriate columns. Refer to Table 1 and Erickson et al. (2008) for optimal mixture inclusion levels associated with WDGS.

- **% DM:** The percent dry matter for each co-product or forage used in the storage procedure should be entered in Cells F24 through F40. The percent dry matter will vary from co-product to co-product as well as from plant to plant. Contacting the ethanol plant from which the co-product would be purchased would provide the best estimate of co-product percent dry matter. See Table 2 for common ethanol co-product dry matter percentages (Erickson et al., 2008).
- **% Crude Protein (Dry Matter Basis):** The percent crude protein (CP; dry matter basis) for each co-product or forage used in the storage procedure should be entered in Cells G24 through G40. The percent CP will vary from co-product to co-product as well as from plant to plant. Contacting the ethanol plant from which the co-product would be purchased would provide the best estimate of co-product percent CP. See Table 2 for common ethanol co-product CP percentages on a dry matter basis (Buckner et al., 2008).

▪ **% Total Digestible Nutrients (Dry Matter Basis):** The percent total digestible nutrients (TDN; dry matter basis) for each co-product or forage used in the storage procedure should be entered in Cells H24 through H40. The percent TDN will vary from co-product to co-product as well as from plant to plant. Contacting the ethanol plant from which the co-product would be purchased would provide the best estimate of co-product percent TDN. Although Table 2 shows common ethanol co-product TDN percentages on a dry matter basis, the TDN percentages shown are averages as energy values change depending on co-product inclusion level in a ration. Additionally, the percentages are based on UNL feeding performance data and are calculated assuming corn is 90 percent TDN (dry matter basis; Buckner et al., 2008).

▪ **Quantity (As-is):** The tons used (as-is) of each feedstuff should be placed in Cells I24 through I40.

▪ **Price (As-is) (FOB Ethanol Plant for Co-Product):** The price per ton paid (as-is) should be entered in Cells K24 through K40. All ethanol co-product prices should be entered as free on board (FOB) the ethanol plant, while all other feedstuff prices should be entered as FOB the site of storage. If the user chooses to enter the co-product prices as FOB the site of storage, do not include transportation costs in Cells G93 and I93 to avoid double-counting transportation costs.

• **Total Feed Costs:** Individual feedstuff costs are reported in Cells M24 through M40 and are automatically calculated by the spreadsheet. These individual costs (Cells M24 to M40) sum to provide the Total Feed Costs shown in Cell M41.

Step 3: Equipment and Structure Costs (Yellow-colored Box)

• **Rented Equipment and Structures:** In order to store the co-product, some equipment may need to be rented. The rented equipment in this section includes a tractor, mixer, hay grinder, and bagger. If additional equipment is rented that is not listed, enter the name of the item in Cell D51. Structures may also be rented and include an above ground cement bunker, gravel pad, and cement pad. If additional structures are rented that are not listed, enter the name of the item in Cell D55. An operation may also custom-hire someone to

Table 2: Common Ethanol Co-Product Dry Matter (DM), Crude Protein (CP), and Total Digestible Nutrients (TDN) Percentages

Ethanol Co-Product	% DM	% CP[1]	% TDN[1,2]
WDGS	30-35	30	112
DDGS	90	30	112
MWDGS	42-50	30	112
Wet Corn Gluten Feed	40-45	18-20	90
Dry Corn Gluten Feed	90	18-20	72
Sweet Bran®	60	23-24	99
Dakota Bran™ Cake	50	14	94.5
[1]Percentages are based on UNL feeding performance data and are expressed on a dry matter basis [2]The TDN percentages shown are averages as energy values change depending on co-product inclusion level; percentages are calculated assuming corn is 90% TDN (dry matter basis)			

place the co-product in storage. If so, custom-hire costs should be accounted for as rented equipment. If fuel, labor, and/or other supplies are included in the rented or custom hire price per hour, do not include these items in "Other Supplies" or "Other Costs" (Step 4) in order to avoid double-counting these items in the spreadsheet.

- **Quantity:** In Cells G47 through G51, enter the number of hours each piece of rented equipment is used for the co-product storage process. In Cells G52 through G55, enter the number of units (hours, days, months, square feet, etc.) that each structure is used during the storage period. Make sure that the associated quantity of units for the structure(s) coincides with the price per unit reported in Cells I52 through I55. Note that the rented or custom-hire quantity for a bagger is entered as tons.
- **Price:** Input the associated price per unit charged for each piece of equipment or storage structure in Cells I47 through I55. Make sure that the associated price per unit for the structure(s) coincides with the quantity of units reported. For example, if the quantity was entered in square feet, the associated price should be entered as dollars per square feet. Also note that the rented or custom-hire price for a bagger is entered as dollars per ton.

- **Owned Equipment and Structures:** A producer may store co-products without rented equipment and/or structures by using all owned equipment and/or structures. The available equipment and structures listed include tractor, mixer, hay grinder, bagger, above ground cement bunker, gravel pad, and cement pad. If a particular structure or equipment is not listed, enter the "Other Tractor" in Cell D59, the "Other Equipment" in Cell D63, and the "Other Structure" in Cell D67.

- **Total Hours Used Yearly:** The *total hours* each tractor, mixer, hay grinder, bagger, or other equipment are used in *an average year* should be estimated and entered in Cells F58 through F63. Note, this is *not* the number of hours used to complete the co-product storage process.
- **Total Hours this Storage:** The total hours each piece of equipment is used to complete this co-product storage process should be estimated and placed in Cells G58 through G63. These estimated hours will vary by the amount of co-product being stored, the familiarity with storage processes and efficiency, and whether the co-product is being bagged or bunkered.
- **Purchase Cost:** Purchase or construction costs for all tractors, equipment, and structures should be entered in Cells H58 through H67.
- **Proportion of Time Used:** This value is automatically calculated in the spreadsheet. The percentages reported in Cells I58 through I63 are determined by dividing Total Hours this Storage by Total Hours Used Yearly. For example, if a tractor was used 400 hours per year (Cell F58) but only 20 hours during the storage process (Cell G58), the Proportion of Time Used would be five percent $(20 / 400 \times 100 = 5)$. The percentages reported in Cells I64 through I67 are determined by dividing Total Days of Storage (Cell J12) by 365 days.
- **Proportion of Space Used:** In Cells J64 through J67, input the proportion of total structure space that the co-product will occupy. For example, if only half of a cement bunker will be used for storage, enter "50" in Cell J64.

- **Ownership Costs on Equipment and Structures:** Ownership costs are calculated according to the type of equipment and

structure. Baggers, mixers, and hay grinders are grouped together as these items are usually managed and depreciated similarly, while tractors and structures are shown separately in the table represented by Cells H69 through J78.

- **Interest Rate:** The rate of interest paid to borrow money to purchase equipment and structures should be entered in Cells H70 through J70. If a producer's own money is being used (no money is being borrowed), the interest rate is the opportunity cost of investing that money in alternative investments and should therefore still be included.
- **Useful Life (Years):** The useful life of equipment is the time (in years) that the equipment is used. This includes items such as tractors, baggers, mixers, or hay grinders. The previously listed equipment is typically expected to have a 10-year useful life. The useful life may be extended or reduced, respectively, based on use. The useful life of structures is the time (in years) that the structure is used. Concrete floors and walls and gravel bases contribute to the total cost of a structure. These types of items generally have a useful life of 20 years. The life of the structure and equipment is used to calculate ownership costs related to interest and depreciation. Enter the useful life for the bagger/mixer/hay grinder, tractor, and structure in Cells H71 through J71.
- **Salvage Value:** This is the percentage of the original investment that the producer is expected to recover upon sale of the capital asset at the end of its useful life. Structures usually have limited value after an extended life, while equipment may have some salvage (resale or trade-in) value (perhaps 30%). Equipment that has been used extensively may have no salvage value.

Enter the salvage values in Cells H72 through J72.

- **Repairs:** This represents the percentage of the original investment costs that must be spent each year to pay for repairs and maintenance of equipment and/or structures. Structures may have repair costs in the range of 0.5 to 1.5 percent of the original cost, while equipment repair costs may be slightly higher, ranging from 2 to 5 percent, with greater values associated with harsher operating environments. Enter the yearly repair costs as a percent of the original equipment/structure cost in Cells H73 through J73.
- **Taxes:** Annual taxes should be entered as a percent of the original equipment/structure cost in Cells H74 through J74 and represent the percentage of original investment costs on structures and equipment that must be paid annually to cover tax costs.
- **Insurance:** These costs should be entered as a percent of the original equipment/structure cost in Cells H75 through J75 and are the average percentage of the original investment cost that must be paid annually to cover insurance for that particular capital asset. Insurance may average 0.5 percent.
- **Depreciation:** This value is automatically calculated by the spreadsheet and appears in Cells H76 through J76. This straight-line depreciation is calculated as (100% - Salvage Value) / Life Expectancy. It is important to note that the salvage value used in the previous equation is expressed as a percentage of the original investment that the owner is expected to recover upon sale of the capital asset at the end of its useful life.
- **Interest:** This value is automatically calculated by the spreadsheet and appears in Cells H77 through J77.

Interest is calculated as [(Interest Rate / 2) × (1 - Salvage Value)] + (Interest Rate × Salvage Value).

- ▪ **Ownership %:** This value is automatically calculated by the spreadsheet and appears in Cells H78 through J78. Ownership % is the percentage of initial investment that is paid annually to cover the cost of depreciation, interest, repairs, taxes, and insurance. This percentage is multiplied by the purchase cost, the proportion of time used, and the proportion of space used to yield the ownership costs on equipment and structures as reported in Cells K58 through K67 (Holmes, 2003).

- • **Other Supplies:** Other supplies that may be used in the storage process are listed in Cells C81 through C85 and include bag plastic, bunker plastic, plastic weighting material, large round bales for bunker, and fuel. If additional supplies are used that are not listed, enter the name of the supplies in Cells D86 and D87. If fuel and/or bag or bunker plastic are included in the rented or custom-hire price per hour, do not include these items in "Other Supplies" in order to avoid double-counting these items in the spreadsheet. It is also important to note that plastic weighting materials (e.g., tires) that are used repeatedly throughout an operation do not have to be included, as the cost for these items allocated over the useful life of the item is negligible. If plastic weighting materials were purchased solely for the use of storing ethanol co-products, then include this item and associated costs in the spreadsheet.

  - ▪ **Quantity (As-is):** The amount used for each supply item should be placed in Cells G81 through G87. The units of measurement associated with the supplies used need to be carefully considered (and should be consistent with Cells H81 to H87) as the units change for different supplies. The

amount entered for large round bales should be included as tons on an as-is basis. If the large round bales used for storage will be fed, do not include this item in the spreadsheet.

  - ▪ **Price (As-is):** The price per unit for each supply item should be placed in Cells I81 through I87. The units of measurement associated with the supply prices need to be carefully considered (and should be consistent with Cells H81 to H87) as the units change for the different supplies. The price entered for large round bales should be included as price per ton on an as-is basis. If the large round bales used for storage will be fed, do not include this item in the spreadsheet.

- • **Total Equipment and Structure Costs:** Individual equipment and structure costs are reported in Cells K47 through K87 and are automatically calculated in the spreadsheet. These individual costs (Cells K47 through K87) sum to provide the Total Equipment and Structure Costs shown in Cell K88.

Step 4: Other Costs (Blue-colored Box)

- • **Transportation:** Because ethanol co-products are typically priced FOB the ethanol plant, transportation costs must be included as a separate item. The number of miles from the site of storage to the ethanol plant should be entered in Cell G93. The price of transportation per loaded mile should be entered in Cell I93. If the co-product price(s) were entered as FOB the site of storage in Step 2, do not include this item (transportation costs) in the spreadsheet in order to avoid double-counting.

- • **Labor:** The total number of hours required to place the co-product in storage should be entered in Cell G94. The price per hour for labor should be placed in Cell I94. If labor is included in the rented or custom-hire price per hour, do not include

this item in "Other Costs" in order to avoid double-counting this item in the spreadsheet.

- **Interest on Feed and Supplies:** This value is automatically calculated in the spreadsheet and appears in Cell K95. Feed and supply items charged interest are denoted with an asterisk (*) in Column B. The interest on feed and supplies is calculated as [(Days of Storage Before Feeding / 365) × (Interest Rate on Feed and Supplies) × (Total Feed Costs + Other Supply Costs)] + [((Days of Storage During Feeding / 365) × (Interest Rate on Feed and Supplies) × (Total Feed Costs + Other Supply Costs) / 2)].

- **Total Other Costs:** The total of individual other costs are reported in Cells K93 through K95 and are automatically calculated by the spreadsheet. These individual costs (Cells K93 through K95) sum to provide the Total Other Costs shown in Cell K96.

Results Summary (Orange-colored Box; Located at Top of Spreadsheet)

- **Total Mixture Cost:** This value is automatically calculated by the spreadsheet and is the sum of Total Feed Costs (Cell M41), Total Equipment and Structure Costs (Cell K88), and Total Other Costs (Cell K96). This value is reported in Cell F4 (as-is basis) and Cell G4 (dry matter basis). Cell F4 and Cell G4 will always be equal to one another because total cost is the same whether reported on an as-is basis or dry matter basis. Only total cost *per ton* will differ between as-is and dry matter.

- **Mixture Cost per Ton Without Shrink:** This value is automatically calculated by the spreadsheet. The as-is Mixture Cost per Ton Without Shrink is reported in Cell F5 and is calculated by dividing Total Mixture Cost (Cell F4) by Tons of Mixture Before Shrink (Cell F14). The dry matter Mixture Cost per Ton

Without Shrink is reported in Cell G5 and is calculated by dividing the as-is Mixture Cost per Ton Without Shrink (Cell F5) by the percent dry matter of the stored mixture. The percent dry matter of the stored mixture is calculated by dividing the dry matter Tons of Mixture Before Shrink (Cell G14) by the as-is Tons of Mixture Before Shrink (Cell F14).

- **Mixture Cost per Ton With Shrink:** This value is automatically calculated in the spreadsheet. The as-is Mixture Cost per Ton With Shrink is reported in Cell F6 and is determined by dividing Total Mixture Cost (Cell F4) by Tons of Mixture Remaining After Shrink (Cell F15). The dry matter Mixture Cost per Ton With Shrink is reported in Cell G6 and is calculated by dividing the as-is Mixture Cost per Ton With Shrink (Cell F6) by the percent dry matter of the stored mixture.

- **Shrink Cost per Ton:** This value is automatically calculated by the spreadsheet. The as-is and dry matter Shrink Cost per Ton are reported in Cell F7 and Cell G7, respectively, and are determined by subtracting the Mixture Cost per Ton Without Shrink (Cells F5 and G5, respectively) from the Mixture Cost per Ton With Shrink (Cells F6 and G6, respectively).

- **Co-Product Cost per Ton Without Shrink:** This value is automatically calculated in the spreadsheet. The as-is Co-Product Cost per Ton Without Shrink is reported in Cell F8 and equals the Total Mixture Cost (Cell F4) less the total co-product costs (sum of Cells M24 to M32) and transportation costs (Cell K93). This result is then divided by as-is Tons of Mixture Before Shrink (Cell F14) and multiplied by the percentage of co-product in the total mixture (Tons of Co-Product Before Shrink [Cell F16] divided by Tons of Mixture Before Shrink [Cell F14]). This value is then added to the total co-product costs per ton (sum of Cells K24 to K32) and

the transportation cost per ton (transportation costs [Cell K93] divided by Tons of Co-Product Before Shrink [Cell F16]). The dry matter Co-Product Cost per Ton Without Shrink is reported in Cell G8 and equals the Total Mixture Cost (Cell F4) less the total co-product costs (sum of Cells M24 to M32) and transportation costs (Cell K93). This result is then divided by as-is Tons of Mixture Before Shrink (Cell F14). This value is divided by the percent dry matter of the mixture (dry matter Tons of Mixture Before Shrink [Cell G14] divided by as-is Tons of Mixture Before Shrink [Cell F14]) and multiplied by the percentage of co-product in the total mixture (Tons of Co-Product Before Shrink [Cell G16] divided by Tons of Mixture Before Shrink [Cell G14]). This value is then added to the total co-product costs per ton, on a dry matter basis, and the transportation cost per ton (transportation costs [Cell K93] divided by Tons of Co-Product Before Shrink [Cell F16]). The total co-product costs per ton are calculated by dividing each respective co-product price per ton (Cells K24 through K32) by the respective percent dry matter (Cells F24 through F32). These values for each co-product are then summed to get the total co-product costs per ton, on a dry matter basis.

- **Co-Product Cost per Ton With Shrink:** This value is automatically calculated in the spreadsheet. The as-is Co-Product Cost per Ton With Shrink is reported in Cell F9 and equals the Total Mixture Cost (Cell F4) less the total co-product costs (sum of Cells M24 to M32) and transportation costs (Cell K93). This result is then divided by as-is Tons of Mixture Remaining After Shrink (Cell F15) and multiplied by the percentage of co-product in the total mixture (Tons of Co-Product Remaining After Shrink [Cell F17] divided by Tons of Mixture Remaining After Shrink [Cell F15]). This value is then

added to the total co-product costs per shrunk ton (sum of Cells K24 to K32) and the transportation cost per shrunk ton (transportation costs [Cell K93] divided by Tons of Co-Product Remaining After Shrink [Cell F17]). The total co-product costs per shrunk ton are calculated by multiplying each respective co-product price per ton (Cells K24 to K32) by the respective quantity of co-product (Cells I24 through I32). The multiplied values for each co-product are then divided by the respective quantity of co-product (Cell I24 through I32) multiplied by one minus the percent shrink (Cell J5). These values, for each co-product, are summed to get the total co-product costs per shrunk ton. The dry matter Co-Product Cost per Ton With Shrink is reported in Cell G9 and equals the Total Mixture Cost (Cell F4) less the total co-product costs (sum of Cells M24 to M3) and transportation costs (Cell K93). This result is then divided by as-is Tons of Mixture Remaining After Shrink (Cell F15). This value is divided by the percent dry matter of the mixture (dry matter Tons of Mixture Remaining After Shrink [Cell G15] divided by as-is Tons of Mixture Remaining After Shrink [Cell F15]) and multiplied by the percentage of co-product in the total mixture (Tons of Co-Product Remaining After Shrink [Cell G17] divided by Tons of Mixture Remaining After Shrink [Cell G15]). This value is then added to the total co-product costs per shrunk ton, on a dry matter basis, and the transportation cost per shrunk ton (transportation costs [Cell K93] divided by Tons of Co-Product Remaining After Shrink [Cell F17]). The total co-product cost per shrunk ton is calculated by multiplying the dry matter co-product cost per ton for each co-product (Cells K24 to K32 divided by Cells F24 to F32, respectively) by the dry matter quantity of each respective co-product (Cells I24 to I32 multiplied by Cells F24 to F32,

respectively). This value for each co-product is then divided by the dry matter quantity of each respective co-product (Cells I24 to I32 multiplied by Cells F24 to F32, respectively) multiplied by one minus the percent shrink (Cell J5). These values, for each co-product, are then summed to get the total co-product costs per shrunk ton, on a dry matter basis.

- **Mixture Cost per Pound of CP Without Shrink:** This value is automatically calculated by the spreadsheet. The as-is Mixture Cost per Pound of CP Without Shrink is reported in Cell F10 and equals the as-is Mixture Cost per Ton Without Shrink (Cell F5) divided by 2000. This value is then divided by the as-is weighted average percent crude protein of the mixture. The as-is weighted average percent crude protein of the mixture is calculated by dividing each respective as-is feedstuff quantity (Cells I24 through I40) by the as-is Tons of Mixture Before Shrink (Cell F14). This value, for each respective feedstuff, is then multiplied by the respective as-is percent crude protein of each feedstuff [percent crude protein (dry matter basis; Cells G24 through G40) multiplied by the percent dry matter of each feedstuff (Cells F24 through F40)]. Each individual feedstuff percentage is then summed to get the as-is weighted average percent crude protein of the mixture. The dry matter Mixture Cost per Pound of CP Without Shrink is reported in Cell G10 and equals the dry matter Mixture Cost per Ton Without Shrink (Cell G5) divided by 2000. This value is then divided by the dry matter weighted average percent crude protein of the mixture. The dry matter weighted average percent crude protein of the mixture is calculated by dividing each respective dry matter feedstuff quantity [as-is feedstuff quantity (Cells I24 through I40) multiplied by the percent dry matter of each feedstuff (Cells F24 through F40)] by the dry matter

Tons of Mixture Before Shrink (Cell G14). This value, for each respective feedstuff, is then multiplied by the respective dry matter percent crude protein of each feedstuff (Cells G24 through G40). Each individual feedstuff percentage is then summed to get the dry matter weighted average percent crude protein of the mixture.

- **Mixture Cost per Pound of CP With Shrink:** This value is automatically calculated by the spreadsheet. The as-is Mixture Cost per Pound of CP With Shrink is reported in Cell F11 and equals the as-is Mixture Cost per Ton With Shrink (Cell F6) divided by 2000. This value is then divided by the as-is weighted average percent crude protein of the mixture. The as-is weighted average percent crude protein of the mixture is calculated by multiplying each respective as-is feedstuff quantity (Cells I24 through I40) by one minus the percent shrink (Cell J5). This value, for each feedstuff, is then divided by the as-is Tons of Mixture Remaining After Shrink (Cell F15). This value, for each respective feedstuff, is then multiplied by the respective as-is percent crude protein of each feedstuff [percent crude protein (dry matter basis; Cells G24 through G40) multiplied by the percent dry matter of each feedstuff (Cells F24 through F40)]. Each individual feedstuff percentage is then summed to get the as-is weighted average percent crude protein of the mixture. The dry matter Mixture Cost per Pound of CP With Shrink is reported in Cell G11 and equals the dry matter Mixture Cost per Ton With Shrink (Cell G6) divided by 2000. This value is then divided by the dry matter weighted average percent crude protein of the mixture. The dry matter weighted average percent crude protein of the mixture is calculated by multiplying each respective dry matter feedstuff quantity [as-is feedstuff quantity (Cells I24 through I40) multiplied by the percent dry matter of each feedstuff (Cells F24 through F40)] by

one minus the percent shrink (Cell J5). This value, for each feedstuff, is then divided by the dry matter Tons of Mixture Remaining After Shrink (Cell G15). This value, for each respective feedstuff, is then multiplied by the respective dry matter percent crude protein of each feedstuff (Cells G24 through G40). Each individual feedstuff percentage is then summed to get the dry matter weighted average percent crude protein of the mixture.

- **Mixture Cost per Pound of TDN Without Shrink:** This value is automatically calculated by the spreadsheet. The as-is Mixture Cost per Pound of TDN Without Shrink is reported in Cell F12 and equals the as-is Mixture Cost per Ton Without Shrink (Cell F5) divided by 2000. This value is then divided by the as-is weighted average percent TDN of the mixture. The as-is weighted average percent TDN of the mixture is calculated by dividing each respective as-is feedstuff quantity (Cells I24 through I40) by the as-is Tons of Mixture Before Shrink (Cell F14). This value, for each respective feedstuff, is then multiplied by the respective as-is percent TDN of each feedstuff [percent TDN (dry matter basis; Cells H24 through H40) multiplied by the percent dry matter of each feedstuff (Cells F24 through F40)]. Each individual feedstuff percentage is then summed to get the as-is weighted average percent TDN of the mixture. The dry matter Mixture Cost per Pound of TDN Without Shrink is reported in Cell G12 and equals the dry matter Mixture Cost per Ton Without Shrink (Cell G5) divided by 2000. This value is then divided by the dry matter weighted average percent TDN of the mixture. The dry matter weighted average percent TDN of the mixture is calculated by dividing each respective dry matter feedstuff quantity [as-is feedstuff quantity (Cells I24 through I40) multiplied by the percent dry matter of each feedstuff (Cells F24 through

F40)] by the dry matter Tons of Mixture Before Shrink (Cell G14). This value, for each respective feedstuff, is then multiplied by the respective dry matter percent TDN of each feedstuff (Cells H24 through H40). Each individual feedstuff percentage is then summed to get the dry matter weighted average percent crude protein of the mixture.

- **Mixture Cost per Pound of TDN With Shrink:** This value is automatically calculated by the spreadsheet. The as-is Mixture Cost per Pound of TDN With Shrink is reported in Cell F13 and equals the as-is Mixture Cost per Ton With Shrink (Cell F6) divided by 2000. This value is then divided by the as-is weighted average percent TDN of the mixture. The as-is weighted average percent TDN of the mixture is calculated by multiplying each respective as-is feedstuff quantity (Cells I24 through I40) by one minus the percent shrink (Cell J5). This value, for each feedstuff, is then divided by the as-is Tons of Mixture Remaining After Shrink (Cell F15). This value, for each respective feedstuff, is then multiplied by the respective as-is percent TDN of each feedstuff [percent TDN (dry matter basis; Cells H24 through H40) multiplied by the percent dry matter of each feedstuff (Cells F24 through F40)]. Each individual feedstuff percentage is then summed to get the as-is weighted average percent TDN of the mixture. The dry matter Mixture Cost per Pound of TDN With Shrink is reported in Cell G13 and equals the dry matter Mixture Cost per Ton With Shrink (Cell G6) divided by 2000. This value is then divided by the dry matter weighted average percent TDN of the mixture. The dry matter weighted average percent TDN of the mixture is calculated by multiplying each respective dry matter feedstuff quantity [as-is feedstuff quantity (Cells I24 through I40) multiplied by the percent dry matter of each

feedstuff (Cells F24 through F40)] by one minus the percent shrink (Cell J5). This value, for each feedstuff, is then divided by the dry matter Tons of Mixture Remaining After Shrink (Cell G15). This value, for each respective feedstuff, is then multiplied by the respective dry matter percent TDN of each feedstuff (Cells H24 through H40). Each individual feedstuff percentage is then summed to get the dry matter weighted average percent TDN of the mixture.

- **Tons of Mixture Before Shrink:** This value is automatically calculated in the spreadsheet. The as-is Tons of Mixture Before Shrink is reported in Cell F14 and equals the total tonnage of feed in the stored mixture (sum of Cells I24 through I40). The dry matter Tons of Mixture Before Shrink is reported in Cell G14 and is determined by multiplying each respective feedstuff tonnage (Cells I24 through I40) by the respective percent dry matter (Cells F24 through F40). The multiplied values, for each feedstuff, are then summed to get the dry matter Tons of Mixture Before Shrink.

- **Tons of Mixture Remaining After Shrink:** This value is automatically calculated by the spreadsheet. The as-is Tons of Mixture Remaining After Shrink is reported in Cell F15 and is determined by multiplying the Tons of Mixture Before Shrink (Cell F14) by one minus the percent shrink (Cell J5). For example, if 200 tons of mixture were stored with 15 percent shrink, 170 tons of mixture would remain after shrink ($200 \times (1 - 0.15) = 170$). The dry matter Tons of Mixture Remaining After Shrink is reported in Cell G16 and is determined by multiplying the dry matter Tons of Mixture Before Shrink (Cell G14) by one minus the percent shrink (Cell J5).

- **Tons of Co-Product Before Shrink:** This value is automatically calculated in the spreadsheet. The as-is Tons of Co-Product Before Shrink is reported in Cell F16 and equals the total tonnage of co-product in the stored mixture (sum of Cells I24 through I32). The dry matter Tons of Co-Product Before Shrink is reported in Cell G16 and is determined by multiplying each respective co-product tonnage (Cells I24 through I32) by the respective percent dry matter (Cells F24 through F32). The multiplied values for each co-product are then summed to get the dry matter Tons of Co-Product Before Shrink.

- **Tons of Co-Product Remaining After Shrink:** This value is automatically calculated by the spreadsheet. The as-is Tons of Co-Product Remaining After Shrink is reported in Cell F17 and is determined by multiplying the as-is Tons of Co-Product Before Shrink (Cell F16) by one minus the percent shrink (Cell J5). The dry matter Tons of Co-Product Remaining After Shrink is reported in Cell G17 and is determined by multiplying the dry matter Tons of Co-Product Before Shrink (Cell G16) by one minus the percent shrink (Cell J5).

Conclusion

Ethanol co-product contracting and storage opportunities exist for cattle feeders and cow/calf operations as illustrated in the co-product seasonal price trend. Several methods are available for the storage of co-products, and operations must identify and refine the optimal strategy for their operation while at the same time ensuring that the benefits of storing the co-product exceed the costs of storage. Co-Product STORE quantifies the costs of co-product storage and allows producers to analyze and evaluate specific storage scenarios in response to changing market conditions.

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