MIXING BEEF FEED RATIONS CONTAINING DISTILLERS WET GRAINS

N. J. Schuler, C. J. Bern, D. D. Loy, T. J. Brumm, D. R. Strohbehn

ABSTRACT. *The flexibility of distillers grains has made it a major substitute for corn in beef feed rations. However, producers are having issues with feeding wet distillers grains. This study addresses three major mixing conditions: ingredient addition order, mixing time, and mixer design. The addition orders considered were hay-corn-protein-DWG and hay-DWG-protein-corn. Horizontal and vertical mixers were tested at mix times of 3, 5, and 7 min mixing a beef finishing ration containing wet distillers grains. Test results were obtained using total mixed ration and Pennsylvania State University Particle Separator analyses. Results showed that the 3-min mixing time is sufficient, thus when adding distillers grains, longer mix times are not needed. The hay- corn-protein- DWG ingredient addition order is recommended for both mixers when using liquid additives in the ration in order to avoid unwanted bundle formation. Finally, the two mixer designs were both adequate in mixing a wet distillers grains ration.*

Keywords. *Distillers wet grains, Mixer wagon, Beef feed ration.*

Corn is one of the most common ingredients in finishing rations for beef cattle. In 2009, the United States produced 336 million Mg (13.2 billion bushels) of corn (USDA, 2010). Corn can serve as the only grain source in back-grounding and finishing diets for beef, and is one of the most affordable, abundant, and sustainable grains grown in the United States. Even though it is relatively low in protein (about 12% dry basis), corn contains almost 70% dry basis starch (OSUE, 2006). However, corn is also the number one export grain in the United States, with roughly 56 million Mg (2.2 billion bushels) being exported in 2009 (RFA, 2009) and because it is so high in starch, it is in demand for uses other than cattle rations, such as ethanol production, snack foods, cereal, corn syrup, and glucose. This high demand for corn is leaving beef producers to look for corn alternatives for use in their rations. With the increase in the number of corn ethanol plants (140 across 22 states) (RFA, 2008), over the past few years, the corn substitute that beef producers are turning to is distillers grains.

DISTILLERS GRAINS

Distillers grains (DGs) are the principal co-product of ethanol production. The two main sources of DGs are beverage alcohol brewers and the growing number of corn ethanol plants (HCE, 2007). The two types of distillers grains are wet distillers grains (DWG) and dry distillers grains (DDG). DWG are about 60% moisture wet basis and DDG are about 10% moisture wet basis (Baskett et al., 2008). To be considered DWG or high moisture, the product must contain more than 50% moisture wet basis. However, drying greatly increases the ethanol plant's energy cost, thus increasing the cost of DDG to the livestock producer. When a soluble syrup co-product is added to DWG, this product becomes distillers dry grains with solubles (DDGS) after drying.

DISTILLERS GRAINS IN RATIONS

DGs have become major substitutes for corn for several reasons. One of those reasons is that DGs are very flexible as feed ingredients. They can be used for energy or as a protein supplement (VeraSun Energy, 2009). This is an advantage over corn alone because of its relatively low protein levels. DG is made up of the non-fermentable components of the corn and is, therefore, rich in cereal proteins, fat (energy), minerals, and vitamins. It is sometimes considered an even better ingredient than corn since it provides energy comparable to corn, but from a non-starch source. This reduces the risk of digestive disorders such as acidosis (VeraSun Energy, 2009). In addition DG improves fiber digestion in the rumen, and is a very flexible component of cattle rations (VeraSun Energy, 2009). For instance, it can be used in creep rations, as a supplement in grazing and high roughage diets, in low phosphorus diets, for wintering cows or developing heifers, and in finish rations for cattle (NCGA, 2008). However, there are some disadvantages to DGs also. These include difficulties with transportation, handling, and the reliability of supply.

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DWG VS. DDG

DWG is usually fed close to where it is produced because of its high weight and short storage life. As a result, valuable nutrients go back on the land in that area with manure. The main disadvantage of DWG is its shorter shelf life (5 to 7 days) compared to that of a dry product such as DDGS (several months) (HCE, 2007). Shipment distance is limited for this reason. Depending on moisture content, special storage facilities may be needed. Finally, since DWG is wet, there is concern about how to best incorporate it into a ration using a mixer wagon. If there is a need for additional equipment to load or mix DWG, this will add to the mix times required and the cost to mix as well. For DDG, the disadvantages include the increased cost for drying, and its lower energy concentration caused from the reduction in digestible energy during the drying of the DDG (OSUE, 2006). Finally, the disadvantages of DWGS/DDGS which contain solubles, are their increased cost to produce, variation in particle size, spoilage, and added transportation costs (HCE, 2007).

ISSUES WITH FEEDING DWG

As with any new ration ingredient, there are issues to be resolved and methods to be refined so as to obtain the best possible mix. In a survey of 2,000 beef producers who use DWG (Baskett et al., 2008), 94 of 228 responders stated that they had experienced problems with mixing and storing DWG. The issues they included (in order of decreasing occurrence):

- order of ingredient addition,
- DWG moisture variation,
- mixing time,
- frozen chunks of DWG,
- metering proper quantities,
- variation in particle size,
- mixer performance.

Recognizing the lack of information available on the mixing process of DWGs, this study was conducted to gain more information on mixing rations.

OBJECTIVE

The objective of this study was to determine the uniformity of ingredient mixing in beef feed rations as measured by particle size distribution and affected by:

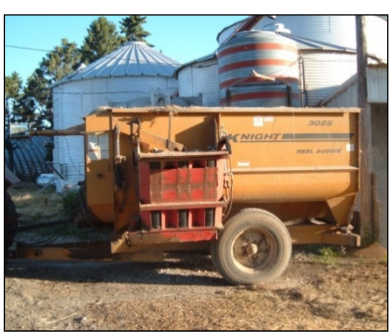
- order in which the ingredients are added,
- mixer design (horizontal vs. vertical),
- mix time (the time from when the last ingredient is added until the mixer is stopped).

MATERIALS AND METHODS

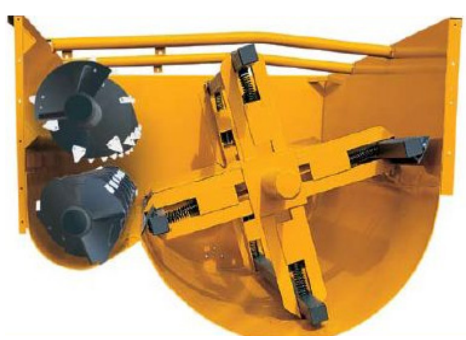
Experimental work was done at a farm near Atlantic, Iowa that feeds approximately 800 steers annually from a starting weight averaging 320 kg (700 lb) to a final weight of 570 kg (1250 lb). The ration used for this study was a finishing feed ration fed to steers weighing about 500 kg (1100 lb) that included four ingredients: tub-ground hay, rolled corn, DWG, and a liquid molasses-based protein supplement. The ration ingredient proportions consisted of 181 kg (400 lb) tub-ground hay (8.2% of ration), 1406 kg (3100 lb) rolled corn (63.9% of ration), 567 kg (1250 lb) DWG (25.8% of ration), and 45 kg (100 lb) liquid protein supplement (2.1% of ration) (Schuler, 2009). The custom ground hay was a mix of 2/3 alfalfa-brome grass and 1/3 corn stalks by weight. Corn was rolled using a static Badger roller mill, model 124X4 (Badger is no longer in business), using corn at 16 to 18% moisture wet basis. The liquid protein supplement (Rumensin 80 Core Max 30) was a molasses-based custom medicated additive (Quality Liquid Feeds Inc., Dodgeville, Wis.) which was delivered directly to the mixer via an electric pump. DWGs were purchased and delivered from the Green Plains Renewable Energy Plant in Shenandoah, Iowa.

TEST EQUIPMENT

Equipment used for the project included two test mixers, one mixer tractor, and one front end loader tractor. The mixer tractor was a 2008 New Holland Model #T6080 (New Holland Agriculture, New Holland, Pa.) rated at 97 kW (130 hp). The front end loader tractor was a 2008 John Deere Model #5425 (Deere and Company, Moline, Ill.) rated at 63 kW (85 hp). The reel/auger horizontal mixer was a rebuilt Kuhn Knight Reel Auggie Model #3025 mixer (Kuhn North America Inc., Brodhead, Wis.) (fig. 1a) with a mixing capacity of 7.1 m³ (250 ft³). This mixer uses a system of augers and a large rotating reel (fig. 1b) to mix the ration by gently lifting and tumbling all the feed ingredients. The large 150-cm (60-in.) diameter reel works



(a)



(b)

Figure 1. Kuhn Knight Reel Auggie Model #3025 (a); reel and auger system (b) (new, representative photo used with permission of Kuhn North America).

with the two side blending augers with diameters of 46 cm (18 in.) to produce the end-to-end side-to-side mixing action. Each of the two augers is equipped with knives to provide the mixer with the effective hay-handling capabilities needed for beef rations. The discharge from this mixer is a side exit, hydraulic motor-driven variable height slide tray using three augers. This wagon was outfitted with a replacement electronic scale from Digi-Star (Digi-Star, LLC, Fort Atkinson, Wis.). This mixer, purchased new in 2002, was supplied by the cooperator and had seven years of service on all components except the unloading auger flighting, cutting knives, and reel bars which had been replaced two months prior to testing.

The vertical mixer was a new Schuler Single Vertical Model #2820 mixer (Schuler Manufacturing & Equipment Co., Griswold, Iowa)(fig. 2a) with a mixing capacity of 7.93 m^3 (280 ft^3). This mixer uses a single high-speed vertical auger (fig. 2b), to lift and disperse feed to the outside of the chamber, thus creating a whirlpool mixing action. This auger also has the option of being fitted with up to five knives to aid in the processing of high forage rations. However, for our forage ration we included only two knives to help limit the overcutting of the forage since it was already ground. The discharge from this mixer is a front- to-side exit hydraulic motor driven conveyor. This wagon was equipped with an Avery Weigh-Tronix electronic scale (Avery Weigh-Tronix, Fairmont, Minn.).

PROCEDURE

A decision was made to incorporate the mixing order and mixer the producer was already using and then to test an alternative against it. The test load was a 2200 kg (4850 lb) finishing ration the producer was feeding. This size of load corresponds to both manufacturers' recommendations of optimum load size. The two styles of mixers used were the horizontal mixer and the vertical mixer. Standard mix times and addition orders were determined following manufacturer's recommendations for each mixer and incorporating the program the producer already had in place. Both manufacturers recommend five minutes of complete ration mixing. "Complete ration mixing" means that all ingredients have been added and the time starts after the last ingredient has been added. To determine if this was in fact the optimal time, 3- and 7-min complete ration mix times were also tested.

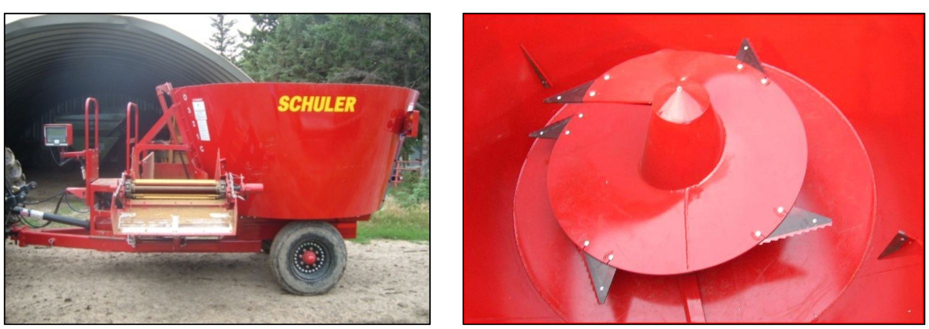
As for addition orders, the test had to involve adding the hay ration first because the instructions for the vertical mixer require that hay be the first ingredient in order to maximize mixing efficiency. The horizontal mixer recommendations were not order specific. To satisfy this recommendation, the test included two ration addition orders: hay-corn-protein-DWG and hay-DWG-protein-corn. Carrying out each combination of two addition orders, two mixer styles, three mix times, and three replications resulted in 36 total tests or 18 per mixer.

TESTING

Each test was conducted as follows. The mixer was started and in operation, mixing at a constant tractor engine speed of 1900 rev/min, which followed the corresponding manufacturers' recommendations. Once the mixer was at speed, the first ingredient (hay) was added. The second ingredient was added approximately 80 s later. This time interval was maintained to keep mixing times constant while an ingredient was not being added. This time of 80 s was chosen because it was the maximum time needed for the loader operator to obtain the next ingredient after adding the previous ingredient. The hay, corn, and DWG were added to the mixer with the JD front end loader. The liquid protein was added via a pump circuit, which dispersed the supplement into the center of the mixers using a rigid mount hose. Once the needed weight of the last ingredient was added, the timer was started and the set mix time for the test was carried out. At the end of the mix time, the mixer was turned off.

SAMPLING

Once a test wagon was mixed and ready to be unloaded, ration samples were drawn by unloading the wagon normally into the bunk, which had five evenly spaced 20-L plastic containers placed between the starting and ending unloading points. So as not to allow disturbance from the livestock, containers were collected from the bunk as soon as the mixer had passed. Once retrieved from the bunk, each container was dumped on a tarp and the container sample was mixed. The container sample was then divided using a quartering technique multiple times; saving opposite quarters for analysis until the needed analysis sample size of about 0.9 L (1 qt) was obtained.



(a) (b)

Figure 2. Schuler Single Vertical Model #2820 (a); vertical auger system (b) (photo used with permission of Schuler Mfg).

Sample Processing

After this analysis sample was gathered from each of the five containers, what remained of the container samples was combined into a single pile, mixed, and a 0.9-L (1-qt) sample was drawn for TMR (total mixed ration) analysis. All 36TMR samples were shipped to Dairyland Laboratories, Inc. (Arcadia, Wis.) for analysis. Dairyland samples were bagged, labeled, and shipped the same day.

Analysis samples were then run through the PSU Particle Separator (Penn. State University, University Park, Pa.) shown on the right in figure 3a. Analysis samples were broken down by the separator into four particle size categories: material on top of a 19-mm (0.75-in.) sieve, material on top of a 7.9-mm (0.31-in.) sieve, material on top of a 1.8-mm (0.07-in.) sieve, and material in the bottom pan (fig. 3b).

After shaking was completed, material on each sieve was weighed. From these weights, converted to percents of sample weights, coefficients of variation (CVs) among the five container samples were calculated. Combinations with CVs of <10% were considered well mixed (Richardson, 1990). Then, since each of the 12 combinations was tested three times, the average and standard deviation were calculated for the three. From these values, along with test observations, results were derived to rate each mixer, each addition order, and each mix time.

Results

Ration Constituents

Table 1 shows the averages, standard deviations, and the CVs of percent moisture, dry matter, percent crude protein, calcium, N D F, phosphorus, magnesium, potassium, sulfur, sodium, and chloride for the samples. Moisture content of the TMR (total mixed ration) averaged 26% wet basis, and crude protein averaged 12% dry basis. Constituents with CVs above 10% were calcium, sodium, and chloride.

Table 1. Ration constituent averages for 36 tests.

Constituent	Mean (%)	St Dev	CV (%)
Moisture content	25.7	1.32	5.14
Dry matter	74.3	1.32	1.78
Crude protein[a]	11.9	0.74	6.22
NDF[a]	18.3	1.60	8.74
Calcium[a]	0.44	0.08	18.18
Phosphorous[a]	0.41	0.02	4.88
Magnesium[a]	0.18	0.01	5.56
Potassium[a]	0.64	0.05	7.81
Sulfur[a]	0.20	0.02	10.00
Sodium[a]	0.12	0.02	16.67
Chloride[a]	0.21	0.03	14.29

[a] Dry basis.

Mixed Ration Variability

Tables 2 and 3 show average CVs and standard deviations for the combined top two trays, which contained mostly forage, and for the bottom tray, which contained the highest percentage of DWG, respectively. Combinations with low CVs correspond to low ingredient variability in the ration. A CV of 10% or less is considered well mixed (Richardson, 1990). Complete data are listed in Appendix B of Schuler (2011). Statistical analyses done using a three factor ANOVA for materials on the top two trays (table 4), and for materials on the bottom tray (table 5), are shown below. ANOVA results with probability values of less than 0.1 show that some difference may exist, and values of 0.05 or less show that a significant difference exists.

Order of Ingredient Addition

Statistical analyses showed there were no significant differences in CVs between the two addition orders for either the combined top two trays (forage) or for the bottom tray (DWG). However, test observations showed that when using liquid additives, adding DWG before the liquid results in bundle formation (fig. 4a and b). Due to the randomness and scarcity of the bundles, none made it into the smaller samples actually analyzed. Size and number of bundles throughout the mix didn't change as mix time was increased. Also, the different styles of mixers had no effect. Bundles of similar size and number were present in both mixers. With the addition order of hay-corn-protein-DWG where the DWG was added last, there were no bundles. Due to a significant amount of liquid additive being trapped in these bundles, the dispersion of the liquid protein containing Rumensin throughout the ration was hindered. In order to have the most effective and safe feed ration when using DG with liquid additives (both those with and without Rumensin), we recommend adding DG toward the end of the mixing addition order, and to add any liquid additives prior to the DG.

Mix Time

For the top two trays, 3-min mix times had significantly lower CVs than either the 5- or 7-min times. CVs for 5- and

(a)

(b)

Figure 3. Penn. State Particle Separator on far right (a); four separator sieves and contents (b).

Table 2. Average CVs and standard deviations for the combined top two trays (mostly forage).

Mix Time (min)	Horizontal Mixer CV (sd)		Vertical Mixer CV (sd)	
	Order of Addition		Order of Addition	
	Hay-Corn-Protein-DWG (1)	Hay-DWG-Protein-Corn (2)	Hay-Corn-Protein-DWG (1)	Hay-DWG-Protein-Corn (2)
3	6.0 (3.6)	4.7 (2.3)	5.3 (2.1)	6.3 (2.5)
5	10.3 (4.0)	7.0 (1.7)	8.3 (1.5)	8.7 (2.5)
7	7.3 (1.5)	9.7 (0.6)	6.0 (1.0)	9.3 (1.2)

Table 3. Average CVs and standard deviations for bottom tray (mostly DWG).

Mix Time (min)	Horizontal Mixer CV (sd)		Vertical Mixer CV (sd)	
	Order of Addition		Order of Addition	
	Hay-Corn-Protein-DWG (1)	Hay-DWG-Protein-Corn (2)	Hay-Corn-Protein-DWG (1)	Hay-DWG-Protein-Corn (2)
3	10.7 (4.5)	9.3 (2.1)	6.0 (2.6)	7.3 (2.3)
5	9.0 (1.7)	10.3 (0.60)	7.0 (1.0)	10.0 (3.0)
7	11.3 (3.5)	8.3 (4.0)	5.0 (1.7)	8.0 (2.6)

Table 4. Analysis of variance for fixed effects on top two trays.

Effect	Num DF	F Value	Pr > F
Mixer	1	0.05	0.8278
Time	2	6.00	0.0077
Mixer*Time	2	0.26	0.7747
Order	1	0.26	0.6125
Mixer*Order	1	2.37	0.1367
Time*Order	2	2.86	0.0769
Mixer*Time*Order	2	0.26	0.7747

Table 5. Analysis of variance for fixed effects on bottom tray.

Effect	Num DF	F Value	Pr > F
Mixer	1	8.27	0.0083
Time	2	0.39	0.6841
Mixer*Time	2	0.63	0.5397
Order	1	0.63	0.4341
Mixer*Order	1	3.60	0.0699
Time*Order	2	0.63	0.5397
Mixer*Time*Order	2	0.52	0.6007

7-min mix times were not significantly different (tables 2 and 4). For the bottom tray, there were no significant differences among mix times. These results show that a 3-min mix time is appropriate for rations containing DWG, and produces a better mix than the 5-min times recommended by mixer wagon manufacturers.

Mixers

The CVs for the two mixers were not significantly different for forage (top two trays). For DWG (bottom tray), the vertical mixer's CV was significantly lower than the CV for the horizontal mixer.

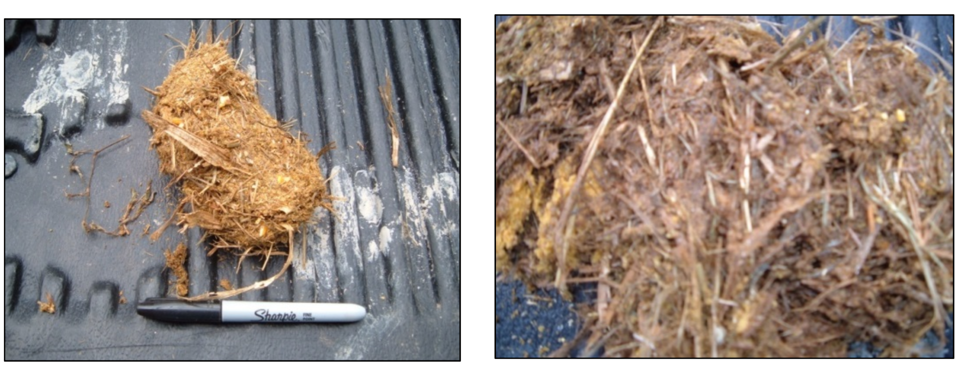
Discussion

For conditions tested in this experiment, adding DWG to a feed ration is not a process that requires major changes to any current mixing process a producer may have. The manufacturers' recommended mixing time of five min is more than enough time to adequately mix DWG into feed rations as test results proved that three min is the optimum mix time. For the order of ingredients, it is necessary to add DWG last or at least after any liquid additives to avoid clumps from forming. This is especially important if using a liquid based protein that has a higher viscosity. Adding the corn second and before the liquid protein seems to provide a firm surface for the protein to attach to within the mix to prevent unwanted clumps from forming. Depending on the mixer style, it may be necessary to add the roughage first. As for mixer style, the vertical style mixer proved to be the better choice for DWG rations when using the recommended addition order. Additional research is needed to confirm our results when using different ingredients and different moisture contents. Further study is suggested on feed trials for beef cattle when rations containing DWG are used.

Conclusions

Based on research reported here, these conclusions can be drawn:

- Uniformity of mix did not vary significantly between the hay-corn-protein-DWG and the hay-DWG-



(a) (b)

Figure 4. Hay and liquid protein bundle (a); Close-up of inside of a hay liquid protein bundle (b).

protein-corn addition orders. However, DWG should be added after any liquid to avoid formation of bundles.

- The vertical mixer and the horizontal mixer gave about the same uniformity of the forage fraction, but the vertical mixer provided a more uniform mix of the DWG fraction. Both mixers provided adequate mixing of the ration.
- -A 3-min mix time yielded a more uniform mix than either the 5- or 7-min mix times for the forage fraction. For the DWG fraction, there were no significant uniformity differences among the mix times.

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