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AS1641

Improving Profitability Through Feed Efficiency by Reducing Feed Bunk Losses

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Feed costs will continue to represent the largest single expense for livestock operations, especially on dairy farms.

With escalating feed prices, all aspects of the dairy should be examined for opportunities to improve efficiencies to reduce shrinkage, including losses at the bunk.

What is shrinkage? It simply is defined as the amount of feed delivered to or raised on the farm that is not consumed by the cattle for which it was intended. However, if you don't measure the shrinkage, you can't manage it.

Shrinkage Can Be Costly

Feed shrinkage is caused by many factors, including delivery weight errors, wind, birds, rodents, tires, tracked feed, cattle tossing feed, silage bunker losses, feed refusals, bunk heating and spoilage, moisture losses, mixing errors, scale accuracy, push-up blades, comingling of ingredients, feed wasted by feeders and drives, feed bunk management, plastic management, moving/storing feed and water damage.

What is typical? You always are going to have some shrinkage, and, of course, the goal should be to minimize it. For example, in a recent study by an Arizona dairy, the managers measured shrinkage during a 60-day period. They found losses of mill-run feed of more than 16 percent, dry distillers grain of more than 9 percent, commercial soybean meal of more than 9 percent, alfalfa hay of more than 7 percent and corn silage of more than 16 percent.

The nutrition consultant for this dairy helped it reach a goal of only 5 percent shrinkage. The value of all feed lost at 5 percent was nearly $175,000 per year, based on 2012 feed prices, compared with the 12 percent, or nearly $420,000, of lost feed the previous year. That means the dairy saved $245,000 when it put the effort into reducing shrinkage. These losses occurred on a 1,000-cow dairy and included the cost of the feed for the milking herd, dry cows and heifers, but not the calves.

High feed costs and low milk prices increase the importance of reducing the overall feed cost. Lowering feed shrinkage is an economic opportunity for nearly all dairies of any size. Shrinkage comes in many forms, and many factors result in feed waste. Feed shrink can represent from 5 to 15 percent of the total feed cost on the dairy, and wet, as well as the more expensive, ingredients represent the greatest concern for farm managers.

NDSU EXTENSION SERVICE

August 2013

Bunk Management

Understanding Feed Efficiency

Feed efficiency may be called milk production efficiency or dairy efficiency, but all these refer to the same thing: how efficiently a dairy cow converts feed to milk. Far more important than the name is how this efficiency can affect a dairy's bottom line.

The potential impact of feed efficiency on the economic performance of the dairy enterprise is undeniable. From the perspective of efficiency, if feed waste is reduced and production (such as milk yield or pounds gained) is maintained, then when waste is reduced, efficiency will improve. Certainly, you have several ways to analyze efficiency, but the critical point to keep in mind is if you can't measure it, you can't manage it.

An improvement in feed efficiency for the milking herd can result in three possible scenarios:

1) An increase in milk yield with no change in feed intake
2) A decrease in dry-matter intake (DMI) with no change in milk yield
3) A slight increase in milk yield with a slight decrease in feed intake

Regardless of your approach as a manager, watch for trends in the herd or on a farm through time. Ultimately, you are attempting to reduce costs and increase income.

One simple way to improve feed efficiency is to employ good bunk management.

For example, when feeding heifers to exact levels of intake, using the heifers' inherent nature to sort feed as a guide to manage bunks has been demonstrated to improve feed efficiency (Hoffman 2007). Paying proper attention to eating behavior and managing the feed bunk accordingly can increase feed efficiency and decrease feed cost.

Bunk Design and Space

It all starts with bunk design. Feed is meant to be consumed by animals. For example, a properly designed feed bunk for heifers should, first and foremost, minimize feed losses behind the feed bunk. University research data has demonstrated that up to 20 percent of feed can be lost to the aft (behind) side of the feed bunk.

A comprehensive study conducted at the Michigan State University beef cattle teaching and research center examined the relationships among feeder design, animal behavior and hay waste. Twenty cows were allotted to one of eight pens with four feeder designs: cone, ring, trailer or cradle. Alfalfa and orchard grass round bales were weighed and sampled before feeding. Hay that fell onto the concrete surrounding the feeder was considered waste, collected and sampled daily.

Dry hay waste ranged from 3.5 to 14.6 percent for the various feeders. Cows feeding from the cradle feeder had nearly three times the agonistic interactions (head butting and displacement of other cows) and four times the frequency of feeder entrances compared with cows feeding from the other feeder types. Feed losses were correlated positively with agonistic interactions and feeder entrances.

This beef cow and forage-only study revealed that design features are important in reducing the amount of hay waste associated with feeding in round-bale feeders.

Purchasing new feeders may not always be a practical way of controlling costs and keeping depreciation expenses low. However, the cost of hay waste alone can be substantial, especially when the hay price is relatively high. The value of reducing hay waste from 30 to 10 percent for a 20-cow feeder (Buskirk 2003) for 200 days, with hay valued at $100 per ton, was estimated at $1,942 annually per feeder.

In general, feed losses for dairy heifers will be less when fed in equipment designs that require the animals to place their head through and reach down for feed as opposed to simply reaching horizontally for feed. Feed wagons, where the feed is at the same horizontal plane as the animal's muzzle, have been demonstrated to increase feed losses.

Fence line feed bunks should be fitted properly for each size group of heifers. Post and rails, throat guards and/or self-locks should be checked and adjusted to proper dimensions. Producers wishing to limit-feed dairy heifers should follow the bunk space requirements for when "all animals eat at once" in Table 1.

Table 1. Minimum bunk space requirements and suggested dimensions for post- and rail-feeding fences and waterers.

Months of age	3-4	5-8	9-12	13-15	16-24
	Inches per head				
Feed always available:					
Hay or silage	4	4	5	6	6
Mixed ration or grain	12	12	12	18	18
All animals eat at once:					
Hay, silage or ration	12	18	22	26	26
	Height, inches				
Throat	–	14	16	17	19
Neck rail	–	28	30	34	41
Maximum water	–	29	31	33	34

Source: P. Hoffman, University of Wisconsin, June 2009

Feed Sorting

Research at the University of Wisconsin has demonstrated that heifers will sort feed very similarly to lactating dairy cows. Heifers, like lactating dairy cows, will choose to consume the shortest particles first and refuse long feed particles.

Because long forage particles and corn cobs generally contain more neutral detergent fiber (NDF) or less energy than small feed particles, such as grain, heifers may consume diets higher in energy than formulated. Likewise, if heifers are allowed to refuse long feed particles, heifers will not reach fill limitations as soon and, subsequently, dry-matter intake will increase.

Hoffman (2007) demonstrated the effects of reducing feed offerings to heifers, forcing the heifers to consume all or most long feed particles. A fair assumption from this research is that anytime a producer allows a dairy heifer to waste feed or throw orts away, it increases cost per pound of gain. The result is a slight decrease in feed intake while maintaining the rate of gain and, hence, improved feed efficiency and decreased cost of gain.

Research data from South Dakota State University (Pritchard 1993) suggest heifers (or steers) should not be overfed on a daily basis. Precisely monitoring and controlling feed intakes and feeding heifers to exact intakes (very minimal feed waste) will reduce feed wastage and increase feed efficiency. The combination of proper bunk design and feeding heifers to exact intakes has been shown to result in 10 to 15 percent improvements in feed efficiency. To feed cattle to exact intakes, a bunk scoring vocabulary should be utilized. A simplified bunk scoring vocabulary is found in Table 2.

The objective of a controlled bunk management feeding system is to feed heifers to a bunk score of 1 every day. If bunks are empty (Score 0) or excessive feed is remaining (Scores 2 and 3), then feed intakes are moved up or down in small increments (2 percent daily) to facilitate feeding heifers to a bunk score of 1. This type of feeding management also helps assure heifers consume all large feed particles and feeds such as corn cobs. Full consumption of the diet also assures the formulated diet actually is being consumed in its entirety.

The objective of a controlled bunk management feeding system is to feed heifers to a bunk score of 1 every day. If bunks are empty (score 0) or excessive feed is remaining (scores 2 and 3), then feed intakes should be moved up or down in small increments (2 percent daily) to facilitate feeding heifers to a bunk score of 1. This photo represents a score of 2.

Armentano and Leonardi (1999) and Martin (1999) observed extensive total mixed ration (TMR) sorting in the feed bunk in university and on-farm trials.

Table 2. Simplified feed bunk scoring example.

Score	Definition
0	No feed remaining
1	A few small particles of feed remaining
2	Many feed particles remaining, concrete still visible
3	Large amounts of feed remaining, no bunk concrete visible

Source: P. Hoffman, University of Wisconsin, June 2009

Data on particle size (ANSI, 1988) of TMR and orts and intake indicated that cows sorted against the coarse particles (Armentano and Leonardi, 1999). This was more evident for TMR containing 40 percent than 20 percent (DM basis) alfalfa hay. The variation in sorting among cows was large.

Martin (1999) determined particle size of the TMR at six-hour intervals from feeding on a commercial dairy. The percentage on the top screen of the Penn State – Nasco shaker box at 0, six, 12, 18 and 24 hours after feeding was 9.3, 13.7, 21.5, 27.5 and 58.7 percent, respectively. Cows sorted against the coarse particles.

The intake of coarse particles appeared to be less during hours 0 to 12 after feeding and more during hours 13 to 24 after feeding. For an on-farm evaluation of sorting, analyzing particle size (Lammers et al., 1996) of the TMR and orts is important.

Cows sorted against the coarse particles. This sorting was more evident for total mixed ration containing 40 percent than 20 percent (dry-matter basis) alfalfa hay.

Factors that contribute to sorting include DM content of forage and feed mixes, particle size of forage and mix, cobs present in corn silage, amount of hay added to the feed mix, quality of hay, frequency of feeding, bunk space and feed access time.

If sorting is a problem, then one or more of the following may need to be considered:

- feeding smaller amounts more frequently
- adding less hay to the mix
- processing hay more finely
- using higher-quality hay
- using hay that is more pliable
- processing corn silage
- addition of water to drier TMR
- addition of a liquid molasses product to TMR to bind fines

Social Effects

Shaver (2010) addresses social rank. It often is closely related to factors such as age and body size. Therefore, in the grand scheme of management, special attention to first-calf heifers makes sense. As Botheras (2007) puts it: "These heifers often have lower positions in a group's dominance hierarchy than older cows. Through the effects of aggression at the feed bunk on feeding behavior, it is often found beneficial to manage primiparous cows in a separate group."

However, research investigating the effects on feeding behavior of housing first-calf heifers alone or together with their older cohorts is limited. Phillips and Rind (2001) found that a mixed group of mature and young cows on pasture grazed for less time than either age grouped alone. Krohn and Konggaard (1979) reported first-calf heifers housed separately from older cows increased eating time and had a higher DMI when housed in free stalls.

In contrast, Bach et al. (2006) observed primiparous cows that were loose-housed and milked with a robotic milking unit ate about 30 minutes longer when housed in a mixed-parity group than young cows housed alone. Obviously, more investigation is required to determine if managing age groups separately has any potential benefits on feeding behavior and DMI.

Yet the fact that smaller animals may be intimidated frequently by larger animals when individual animal weight within the group of heifers varies by more than 125 pounds is well-established. Consequently, intake is compromised and growth rates slowed, regardless of feed quality.

> Typically, heifers greater than 400 pounds perform best on pasture or other high-moisture forages.

At weights less than 400 pounds, heifers have a difficult time consuming adequate quantities of high-moisture forages to meet nutrient needs when feed bunk space is limited. Nonetheless, some producers have been successful at feeding excellent-quality, high-moisture forages to smaller animals, provided bunk space or pasture area is adequate.

Meal Pattern

Ruminal pH declines following meals, with the rate of pH decline increasing as meal size increases and dietary NDF concentration decreases (Allen, 1997). Bunk management practices that cause cows to eat fewer and larger meals more quickly may be associated with an increased incidence of ruminal acidosis and laminitis. Factors that can cause slug feeding phenomena of the TMR include:

- limited bunk space
- limited feed access time
- restricted feeding versus feeding for 5 to 10 percent refusal
- inconsistent feeding schedule, infrequent TMR push-up
- feed bunk competition

The combination of limited bunk space (less than 1.5 feet per cow) and time to access feed (less than 16 to 20 hours per day) is worse than either situation alone. Lock-ups decrease the number of spaces available but increase individual cow space and access. When overcrowding of free stalls coincides with limited bunk space, as is often the case, the potential for laminitis is greater because cows may spend more time standing on concrete than lying in stalls (Colam-Ainsworth et al., 1989).

Feeding the TMR in a drive-by bunk at 10 centimeters [4 inches] above the cow alley rather than in an elevated bunk increases salivary flow and reduces sorting (Albright, 1993), which may help reduce acidosis. Milton (1998) reported that feedlot cattle fed to a clean bunk had reduced frequency of meals (4.5 versus 8.2 meals per day) and greater average meal size (7.7 versus 3.5 pounds per meal) than cattle fed ad libitum. Milton (1998) also reported that deviations of two to four hours from a normal feeding schedule greatly increased the risk of acidosis in feedlot cattle. Frequent TMR push-up may encourage cows to come to the bunk more frequently for smaller meals.

First-lactation heifers fed in a separate group spent 10 to 15 percent more time eating and consumed 0.5 to two more meals per day than herd mates grouped with mature cows (Krohn and Konggaard, 1979). Adverse social effects of moving cows between groups on meal frequency, size and duration may be observed but usually last only a week following the move (Grant and Albright, 1997).

Feeding an ionophore (monensin) to feedlot cattle increased meal frequency and reduced average meal size in two trials reviewed by Milton (2000). Nagaraja et al. (1987) reported that several antimicrobial feed additives, including the ionophores monensin and lasalocid, reduced lactic acid concentrations in vitro through their inhibition of the lactic acid producer *Streptococcus bovis*.

Dietary supplementation of sodium bicarbonate buffers the decline in ruminal pH that is observed post-feeding (Erdman, 1988). The recommended inclusion rate for sodium bicarbonate is 0.75 to 1 percent of TMR dry matter.

Feed Wastage Study

While feed losses during feed delivery can be the most significant for many feeds on the farm, they have not been well-documented, with few studies having been done anywhere in the world. In fact, even the methods used to quantify feed wastage rates associated with different feed-out methods have not been well-described.

To address this situation, *Dairy Australia's Grains2Milk* program conducted a study of feed wastage rates on 50 commercial dairy farms that used different feed-out methods. Farms involved in the study spanned the six different feed-out methods described by Little, 2009 as used on Australian dairy farms.

1. **Temporary** – Rations are fed on bare ground under an electric fence line, in hay rings or old tractor tires using existing equipment. The cows are not grazing the paddock where fed, and the paddock commonly is referred to as a sacrifice paddock. This method does not have any prepared surfaces for the feed-out area. In this system, the feed-out facility can be moved readily to other sites around the farm as determined by circumstances, such as when the paddock becomes muddy.
2. **On pasture** – Rations are fed in the pasture where the cows are grazing. The feed usually is placed on the surface or under an electric fence using equipment such as a tractor and bucket or a silage cart.
3. **Semipermanent** – Rations are fed on a semipermanent, compacted surface that uses low-cost troughs, such as conveyor belting, second-hand feed troughs or other materials. The equipment used for feed-out is usually a silage cart or a mixing wagon.
4. **Permanent, basic** – Complex mixed rations are fed out using a purpose-built feed-out facility with a compacted surface that has concrete feed troughs or a narrow cement strip under electric wires or cable to prevent cows from trampling the feed. A mixing wagon usually is used for preparation and feed-out.
5. **Permanent, minimal waste, maximum control** – Complex mixed rations are prepared using a mixing wagon and fed using a purpose-built feed-out facility, most likely with a cement surface for the cows and one or more feed alleys. This may be covered with a roof and may incorporate a loafing area or cow stalls. Headlocks or cabling and, in some cases, an electric wire are used to restrain the cows to prevent feed losses due to trampling.
6. **Grain feeding in the milking parlor** – Supplementary grain or pellets are fed during milking. This system is used in conventional herringbone and rotary dairies. A wide variety of systems are found in dairies, ranging from more advanced and costly equipped parlors to rather basic. In the former example, feed allocation can be altered according to the manager's requirements. In some instances, cows can be fed individually using one or more supplements, and the trough space may be divided among cows using physical barriers (gates or a looped rail) to separate the cows' heads in the trough. The more basic systems delivered one supplement and/or amount, and the trough area had no physical barriers separating the cows from adjoining feed.

Practices that can save feed at the bunk include the following:

Feed Ingredients/Rations

- Pay close attention to chop length when cutting hay and silage.
- Protect hay and silage during storage to minimize dry-matter and quality losses.
- Offer fresh, palatable, high-quality feed at all times to the cows, and discard any spoiled or moldy feed ingredients.
- If feeding a partially mixed ration using a mixer wagon, take care to ensure the mix is not under- or overprocessed;

it should be processed according to the manufacturer's instructions.

- Use ration conditioners such as molasses or oil to reduce fines, sorting of feed and rejection or wastage of feed.

Feeding Infrastructure Design

- Hay feeder design affects the amount of hay wastage. Feeders that encourage cows to keep their heads in the feeder opening, reach for feed and not back away easily, only to drop hay on the ground, are preferred (for example, a slatted bar design on a ring feeder that forces cows to rotate their heads when entering or leaving the feeder).

If using bunks:

- Ensure adequate space for the number of cows (recommend 2.5 feet per cow).
- Aim for a height that allows cows to eat with their head in a natural grazing position – about 4 to 6 inches above the ground – to promote more saliva production.
- Ensure surfaces are smooth to avoid a buildup of waste feed, mold and odors, and ensure they are easy to clean.
- Consider concrete aprons around troughs to prevent mud and slush that contaminates feed and reduces palatability.

Feeding Management

- Offer cows the right amount of feed at the right time of the day; don't overfill troughs.
- Sequence feeds carefully during each 24-hour period.
- Clean feeding surfaces regularly.
- Consider cows' social order (aggressive versus timid cows).
- Adapt to prevailing weather conditions.

Helping the Feeder Minimize Batch Variation

Obviously, the performance of the feeder is an integral component in the accurate preparation of a load of feed. Most of the problems at the bunk are associated with production and procurement challenges before feedstuffs get to the feed yard. So instead of blaming everyone else, communicate! That is the key to team success.

The nutritional consultant, along with the dairy owner or manager, needs to work closely with this individual. Likewise, the feeder must understand how many seemingly small things can have a huge influence on animal performance.

Specifically, feeders need to understand the following areas (Stone 2008):

Basic Feedstuff Issues

- **Dry matter** – What it is, why it is important and how it should be calculated. Bucholtz (1999) reports that most feeders attending Michigan State University Feeder Schools were uncomfortable with arithmetic and had a poor understanding of the DM concept.
- **Face management** – These are methods to keep the silage face straight, with minimal disturbance of packed silage, and minimal amounts of loose feed left at the end of feeding.
- **Silage collection for load preparation** – Silage varies across the vertical face of the silo. Thus, silage used to prepare a load of feed needs to be obtained by uniformly removing silage across the height of the silo.
- **Spoiled silage** – Poor-quality silage that may be along the top and sides of the silo should be removed so that it is not fed and does not impair animal performance.
- **Effect on animal performance** – Layers of poor-quality feed in the bunker have potential effects on animal performance.

Load Preparation Considerations

- Ingredient sequencing and what order works best
- Ingredient accuracy when loading the mixer wagon
- Mixer operation, including length of time and run speed
- Minimum and maximum load sizes
- How operation and load size affect ration particle size
- Mixer wagon maintenance; for example sharp knives, scale accuracy

The feeder has a difficult, but highly important, position on a dairy. Therefore, time and effort spent to make the job easier to achieve the desired results are resources well spent. Purchased or on-site ingredient mixes can be helpful for improving diet accuracy by minimizing the number of ingredients that must be added to each and every load, thus increasing the feeder's speed and accuracy.

Even something as simple as printing load sheets that are in a font style and size that is easy to read from a distance and include multiple forage dry-matter increments and numbers of animals per pen can ensure feeders do their job more precisely. Scale displays should be mounted so they are comfortably visible from the loading tractor. Also, the scale should have a remote that allows it to be zeroed after the addition of each ingredient.

Tom Oelberg (personal communication), dairy field technical specialist with Diamond V, notes dairies that do a commendable job of reducing refusals without negatively affecting performance typically follow these **critical management steps**:

- Measure moisture daily.
- Record weights on refusals.
- Feed pens the same time every day.
- Remove refusals right before feeding so cows are not out of feed.
- Adjust daily feed gradually (0.5 pound of DM/cow/day up or down).
- Communicate pen counts to whoever adjusts load sizes.
- Use feeding software to adjust load sizes automatically and to do split-pen feedings more accurately.

Summary

Feeding behavior of group-housed dairy cows is influenced by management practices at the feed bunk and factors associated with the physical and social environment. The feeding pattern of group-housed dairy cows is largely influenced by the timing of fresh feed delivery, and the delivery of fresh feed has a greater impact on stimulating cows to eat than does the return from milking. Delivering fresh feed more frequently improves access to fresh feed for all cows and reduces sorting of the TMR. This potentially will reduce variation in diet quality consumed by cows, with benefits for milk production.

The use of headlock feed barriers may reduce aggression at the feed bunk and give subordinate cows more access to feed, particularly if cows are overcrowded at the feed bunk. As commonly stated, the basics of feed bunk management are:

"Provide the RIGHT feed to the RIGHT cows at the RIGHT time in the RIGHT place at the RIGHT price." The same considerations apply to managing replacement heifers and dry cows, whether housed and fed in confinement or on pasture."

Take-home Recommendations

Feed bunk management is important for getting cows to consume the ration that has been formulated and mixed in amounts necessary to support growth and milk yield.

The following items should be reviewed to identify any factors that may adversely affect intake (Bernard 2008):

- ❑ Fresh feed should be available immediately after milking. Cows typically eat after milking, and this delays lying down so that the teat sphincter has time to close.
- ❑ Excess feed refusal is expensive, but slick bunks can reduce milk yield. Refusals can be 4 to 5 percent of the amount offered for fresh and high-producing cows but 1 to 2 percent for lower-producing groups of cows.
- ❑ Calculate daily dry-matter intake based on the TMR amount offered, TMR amount refused and ration DM content. Plot the daily intake for each group, along with milk yield, to monitor changes.
- ❑ Evaluate the ration in the feed bunk immediately after feed delivery to make sure it was mixed properly.
- ❑ Use 100 percent of the feed bunk space for feed delivery.
- ❑ Provide 18 to 30 inches of feed bunk space per cow. Fresh cows should have more space than lower-producing cows. Multiple feed deliveries should be made when the amount of bunk space is less than 24 inches per cow.
- ❑ Evaluate the ration approximately four to six hours after feeding and before the bunk is cleaned to determine if the cows are sorting the ration.
- ❑ Push feed toward cows four to six times each day, depending on the number of feedings, to keep feed in reach.
- ❑ During heat stress, feed approximately 65 percent of the ration during the cooler parts of the day and increase the number of feedings.
- ❑ If feed in the bunk is heating, add an organic acid to prevent secondary fermentation.
- ❑ If bunks are pitted, consider fitting them with a plastic liner or resurfacing them. This will encourage greater intake and reduce spoilage.
- ❑ Design feed bunks properly. Dry-matter intake is greater when cows eat with their head down as if they were grazing, curb heights are limited to 21 inches and neck rails are 46 to 48 inches above the floor, providing the cow room to reach feed on the outside of the bunk

> "Reducing waste through more precise feed delivery can reduce feed costs and add revenue to the dairy enterprise."

References

Albright, J.L. 1993. Feeding behavior of dairy cattle. J. Dairy Sci. 76:485-498.

American National Standards Institute. 1988. Method of determining and expressing particle size of chopped forage materials by screening. ASAE S424.

Armentano, L., and C. Leonardi. 1999. Effect of different particle size, quality and quantity of alfalfa hay on selective consumption of dairy cattle. Pages 1-6. In: Proc. UW Arlington Dairy Day. Arlington, Wis. Dairy Science Department, University of Wisconsin-Madison.

Bach, A., C. Iglesias, M. Devant and N. Ràfols. 2006. Performance and feeding behavior of primiparous cows loose housed alone or together with multiparous cows. J. Dairy Sci. 89:337-342.

Botheras, N.A. 2007. The Feeding Behavior of Dairy Cows: Considerations to Improve Cow Welfare and Productivity. Pages 29-42, In: Proc. Tri-State Dairy Nutrition Conference

Bernard, J.K. 2008. Feeding Management: Do's and Don'ts. Pages 18-23. In: Proc. Florida & Georgia Dairy Road Show.

Buskirk, D.D., A.J. Zanella, T.M. Harrigan, J.L. Van Lente, L.M. Gnagey and M.J. Kaercher. 2003. Large round bale feeder design affects hay utilization and beef cow behavior. J. Anim. Sci. 81:109–115.

Colam-Ainsworth, P., G.A. Lunn, R.C. Thomas and R.G. Eddy. 1989. Behavior of cows in cubicles and its possible relationship with laminitis in replacement dairy heifers. Vet. Rec. 125:573-575.

Erdman, R.A. 1988. Dietary buffering requirements of the lactating dairy cow: A review. J. Dairy Sci. 71:3246-3266.

Grant, R., and J. Albright. 1997. Dry matter intake as affected by cow grouping and behavior. Pages 93-103. In: Proc. 58th MN Nutr. Conf. & BASF Tech. Symp. Bloomington, Minn. University of Minnesota Extension.

Hoffman, P.C. 2007. Heifer Management Blueprints. eXtension. *www.extension.org/pages/11542/heifer-management-blueprints:-heifers-and-feed-bunk-management*

Krohn, C.C., and S.P. Konggaard. 1979. Effects of isolating first-lactation cows from older cows. Livest. Prod. Sci. 6:137-146.

Lammers, B.P., D.R. Buckmaster and A.J. Heinrichs. 1996. A simple method for the analysis of particle sizes of forage and total mixed rations. J. Dairy Sci. 79:922-928.

Little, S. 2009. Feed wastage study 2009 – Summary report. Dairy Australia Grains2Milk. *www.dairyaustralia.com.au/~/media/Documents/Animals%20feed%20and%20environment/Feed%20and%20nutrition/Feeding%20Systems%20latest/DA%20Grains2Milk%20feed%20wastage%20study%20-%20summary%20report.ashx*

Martin, R. 1999. TMR particle distribution analysis at six hour time intervals. Pages 7-16. In: Proc. UW Arlington Dairy Day. Arlington, Wis. Dairy Science Department, University of Wisconsin-Madison.

Milton, T. 2000. Managing nutritional disorders with high-grain rations in beef cattle. Pages 65-80. In: Proc. Inter-Mountain Nutr. Conf. Salt Lake City, Utah. Utah State University, Logan, Utah.

Nagaraja, T.G., M.B. Taylor, D.L. Harmon and J.E. Boyer. 1987. In vitro lactic acid inhibition and alterations in volatile fatty acid production by antimicrobial feed additives. J. Anim. Sci. 65:1064-1076.

Phillips, C.J.C., and M.I. Rind. 2001b. The effects on production and behavior of mixing uniparous and multiparous cows. J. Dairy Sci. 84:2424-2429.

Pritchard, R.H. 1993. Bunk management. In: Proc. Delivering the Difference. Land 'O Lakes Arden Hills, Minn.

Shaver, R.D. 2002. Rumen acidosis in dairy cattle: Bunk management considerations. Pages 75-81. In: Proc. 12th International Symposium on Lameness in Ruminants, Orlando, Fla.

Stone, B. 2008. Considerations in Feed Bunk Management. Pages 113-123, In: Proc. Tri-State Dairy Nutrition Conference. Fort Wayne, Ind.

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