Improving Cow Comfort to Reduce Health Issues and Increase Milk Yield on Dairy Farms

A Senior Project

Presented to

The Faculty of the Dairy Science Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

Of the Requirements for the Degree

Bachelor of Science

By

Shonlyn Ferrari

March 2014

Abstract

In recent years the dairy industry has been looking more and more into cow comfort. This is because there are many benefits to ensuring cows are in some of the best new facilities. I looked into some of the major issues relating to cow comfort which include how to improve your own dairy, what health problems are common with inadequate cow comfort, and how these issues relate back to milk yield. First cow comfort is outlined and explained, then health problems are shown to be caused by improper cow care and lastly how cow comfort can improve milk yield. In the end, it was found that all these issues can greatly improve milk yield when combined, each having their own impact. Dairies are spending the money to create better facilities for their cows and are seeing the return through increased milk yield.

Table of Contents

Page

INTRODUCTION

Cow comfort is an idea in the dairy industry that has gained a lot of attention in the past fifteen years. Cow comfort is the thought that dairy cows that are pumping milk for us two to three times a day need to be happy and comfortable in their living facilities away from the milk barn. Comfort is broadly defined and includes adequate space, soft bedding, correctly sized freestalls, enough water and feed, and many other factors. Many aspects of cow comfort involve a cost which is why so many dairy producers are hesitant to make specific changes to their facility. However, these costs will easily pay for themselves by savings on treating sick cows and an increase in milk yield (Krawczel and Grant, 2008). Having uncomfortable cows leads to costly treatments for injuries that can result, such as hock lesions, lameness, slipping, mastitis, and others. These illnesses and injuries are very expensive in terms of treatment costs and, potentially, milk loss. If dairy producers could reduce this, I'm sure they would see an increase in profit. A reduction in injuries and illness would also lead to higher milk yield in the cows. When a cow isn't focusing most of her energy to healing herself, she can put that energy towards producing better and more milk. Many people in the dairy industry are realizing this and putting a lot of time and effort into making their cows as comfortable as possible.

Lying time is one of the key ways that cow comfort is assessed. A cow should spend about twelve to thirteen hours of her day lying (Jensen et al., 2005). If she is not, there is something unappealing about the housing she is kept in (Ito et al., 2009). Lying time is very important because it affects lameness and, in turn, milk yield of a cow (Fregonesi and Leaver 2001; Haley et al., 1999). By monitoring lying time, a dairy producers will be able to detect lame cows more quickly due to their behavior. An increase or decrease in lying time can be an

indicator of lameness (Chapinal et al., 2010). If a cow is not lying for a large part of their day, rumination decreases along with blood flow and growth hormones associated with milk yield (Haley et al., 1999). Dairy producers are realizing how important lying behavior is, which is causing major technological advances in monitoring cow comfort through lying times with an automated pedometer tag (Mattachini et al., 2012). Dairies are realizing how important it is to encourage cows to lie down and make it as easy as possible for them. If cows are able to lie down whenever they want and are not forced to stand for excessive amounts of time to due inadequate facilities, their health will improve (Krawczel and Grant, 2008).

Cow Comfort

Bedding Choices

As many dairy producers know, there are many different options for bedding in freestalls. It's tough to know which one is going to be the best for your dairy. Some common options are manure solids, sand, mattresses, straw, and soft or hard wood sawdust. With many different options, it becomes difficult to decide which one is the best, so many dairy producers go with what is the cheapest and easiest for them to maintain. This doesn't mean the bedding is best for the cows. There are downsides and upsides to each bedding choice, some pertaining to the cow and some to the dairy producers. Manure solids are a cheap form of bedding for dairy producers but may not be the most comfortable option for cows. Manure solids can also be more difficult to keep clean and soft as the bedding can get packed down quite easily and once wet, it takes a while to dry out.

Mattresses can be a good option for a base, but is one of the worst options for bedding. They are shown to increase standing by up to two hours per day which is strongly associated with lame cows (Cook et al., 2005). Mattresses can work well when used with additional bedding. Straw is a comfortable option for cows. However, it has been shown to be harder to keep clean and results in more hock lesions than sand bedding (Norring et al., 2008). Sand bedding is the best option in terms of cow comfort because the cows will readily lie on it when given to them. Sand stays the cleanest (von Gastelen et al., 2011), which results in the least amount of injuries to hoofs and hock lesions and sand can also be recycled (Norring et al., 2008).

Even if you have the correct bedding, your cows may not being lying as much as they should be. This is because bedding needs to be at the correct depth in order to maintain a certain

level of comfort for cows. No matter the surface of the freestalls or open pen, bedding must be used and is very important for lying times. Cows show a strong preference for deeper bedding over little to no bedding, even when using mattresses (Tucker and Weary, 2003; Drissler et al., 2005). Mattresses have been advertised as a way for dairies to avoid a lot of maintenance and still keep their cows comfortable, but this isn't the case. Cows will spend more hours in their day lying down if given freestalls with a heavily bedded mattress compared with a bare or slightly bedded mattress (Tucker and Weary, 2003). Cows also show less perching (standing with two legs in the stall and two legs out) when given more bedding, which leads to fewer hock lesions (Tucker and Weary, 2003). Concrete freestalls with deeper bedding were also preferred compared to mattresses with no bedding (Husfeldt and Endres, 2012). This shows the importance of bedding depth, but this also requires more maintenance and expense to the dairy owner. The benefits of this extra work and money comes through with more comfortable cows.

Freestalls should be maintained by a designated person who ensures bedding is kept at an appropriate depth and is kept clean and dry. Wet bedding can cause comfort problems because cows will not want to lie in it and, if they do, it can lead to diseases acquired from poor sanitation. Keeping the bedding clean is just as important as keeping it soft because cows can easily pick up severe problems like mastitis from lying down in unkempt bedding. Since cows should be lying for a large chunk of their day, this is very problematic. When bedding is kept clean and dry, dairy producers could see a decrease in the number of mastitis infections with their herd. Clean bedding can also prevent hock lesions and other hoof injuries (Norring et al., 2008).

The base material used in freestalls is important because it is the base of what the cows will be lying down on. If this material is softer, the bedding will be softer because the base is what starts the impact on the cow's body when she lies down. Common materials are concrete, rubber mats, multilayer mats and mattresses. These materials, excluding mattresses, are used not only in the freestalls, but typically extend through the rest of the dairy in the traveling lanes and alleys. This is important because if the cows aren't lying, they're standing and what they're standing on must be soft to avoid injuries. Cows can show improvements in milk yield, fewer mastitis cases, and reduced culling with the right type of base. In each case, concrete was the worst material for cows to have in their freestalls (Ruud et al., 2010). Cows prefer softer freestall bases because it is easier for them to lie on, get up, and is just more comfortable. The best material showing significant improvements in milk yield, decrease of clinical mastitis and cow removal was the multilayer mats (Ruud et al., 2010). This is most likely due to the fact that it is multiple layers of soft matting material. This soft base coupled with quality soft bedding can show significant improvements in a dairy operation (Ruud et al., 2010).

Freestall Design

Neck rails are used at most dairies to help keep the stalls cleaner by preventing the cow from going too far into the stall. Some dairies use brisket boards for this purpose, but cows show much less lying time and prefer freestalls without the board altogether (Tucker et al., 2006). If she is stopped by a bar while walking into a stall, she will stop there and lie down. This improves cleanliness by not allowing the cow to go too far into the stall where she urinates and defecates in the stall. The question is the perfect position for the neck rail because it shouldn't be too far into the stall but shouldn't be too close to the curb at the end of the stall. Less restrictive neck

rails placed farther into the stall allow a cow to walk farther into the stall and be more confident with lying down because she fully fits in the stall. This is shown in Fregonesi's et al. 2009 study which observes less perching time in cows with less restrictive neck rails. This in turn helps foot health, but has a downside. Cleanliness is decreased with this position because cows can go further into the stall (Bernardi et al., 2009). With smaller cows, their entire body may be in the stall which means every time they urinate or defecate, it stays in the stall instead of the alleys where it will get washed away more easily. This means more maintenance for the bedding in the freestalls, so is it worth it? Bernardi et al. 2009 also found that lameness decreased significantly for these less restrictive neck rails, which improves milk yield. This is a much greater gain than sacrifice because cows are less lame and have better foot health leading to less medical cost as well. Wider freestalls are preferred by cows because they will spend about an hour longer per day lying in these roomier stalls (Tucker et al., 2004). This does lead to slightly dirtier stalls, but if they are being properly maintained for bedding already, it should not be a problem. The increased stall maintenance is a small price to pay for these other great improvements.

Stocking Density

The number of cows compared to how many headlocks or freestalls are available in a given pen is an important factor because cows need to have enough room to move around, to lie down whenever they would like, and to get enough water and feed bunk space. When cows are overstocked, or above a one to one ratio of cows to headlocks or freestalls, they have less access to freestalls and feed due to increased competition. More dominant cows will displace cows that are already lying down due to lower freestall access (Fregonesi et al., 2007). There is a clear indication that higher stocking density increases aggressive physical interactions between cows

(Fregonesi et al., 2007; Fregonesi and Leaver, 2002). Since cows are innately herd animals, the less aggressive actions towards each other, the better they will live together. Overstocking has its greatest impact on cow lying time. This is because cows will not all be able to lie at the same time in an overstocked pen. That they would all want to lie down simultaneously is unlikely, but they do not even have the option. Overstocking above 113% showed a much higher number of cows standing in alleys meaning they could not access a freestall even though they wanted to lie down (Krawczel and Grant, 2008). When cows are overstocked, lying time is reduced greatly even though cows will lie down much more quickly after returning from the parlor when overstocked by 150% (Fregonesi et al., 2007). This may seem beneficial at first but by lying down immediately after milking, the risk of environmental mastitis increases along with reduced feed intake because cows will choose to lie down instead of going to the feed bunk (Fregonesi et al., 2007). For all these reasons, it is very important to keep cows in pens that are large enough to hold the number of cows in them and, preferably, for each cow to be able to lie in a sizable freestall whenever they would like.

Thermal Stress

Heat stress is a well known problem with many different potential solutions. Some of the information may vary, but much of it is similar. Cows have a low tolerance for heat at temperatures as low as 16 degrees Celsius (Hammami et al., 2013). Humidity also greatly affects heat tolerance due to a slower rate of evaporative cooling from sweating (West, 2003). The breed of cattle on a dairy also contributes to the significant heat stress effects. Jersey cows will be less prone to heat stress showing continually lower rectal temperatures than Holsteins because they have a larger surface area to volume ratio (Smith et al., 2013). Kadzere et al. (1999) found that

heat stress will cause cows to have decreased fat and protein components, negatively affected milk yield and can lead to death. Also, animals with higher milk production will reach their upper critical temperature faster than lower producing animals due to increased feed intake. This is because when feed intake rises, more metabolic heat is produced making it more difficult for a cow to maintain homeostasis. In the end, it is essential to provide as many tools as possible to help cows cool down during the summer months to ensure their lives and milk production stay consistent.

Overheating cattle can be detrimental to a dairy operation which is why there are many different techniques for cooling cows during the hottest months of the year. One of the most basic ways to help a cow cool down is allowing them to be under plenty of shade. In areas with adequate shade body temperatures of cows will stay closer to their normal range (Tucker et al., 2007). Some of the best tools are misters or soakers and fans throughout the barn where the cows spend most of their time (Collier et al., 2006). This is usually in the freestall area where bedding should still be deep and soft, but now there may be a problem with getting it wet because it still needs to be dry. This is where sand comes in as the best bedding once again (Calegari et al., 2011). Since sand is inorganic it has the least bacteria naturally in it and absorbs liquid better than other organic beddings (von Gastelen et al., 2011). Some dairies choose fans or misters, but they are not as effective unless used together (West, 2003). Misters are used to soak the cows with water while the fans blow across the cows creating evaporative cooling. This is the most effective way to help an animal lose heat in any given environment (West, 2003). The effectiveness of these in conjunction with each other is also dependent on how close the misters are from the cows (Collier et al., 2006). If they are too far, it is not as effective because the water

may get blown away before reaching the cow. Some people prefer soakers over misters but as long as the cow is getting water deeper than just fur surface, either one will work well (Collier et al., 2006). Installing shade is the easiest way to improve heat stress, but misters and fans are necessary when living anywhere that gets warmer than 25 degrees C. Dairy producers should incorporate all three of these items to prevent current and future problems due to heat stress.

Health Issues

Lameness

There are many health problems that can be avoided with excellent cow comfort which many dairy producers do not realize. One of the big problems is lameness among cattle and is directly influenced by lying time (Keyserlingk et al., 2009). Lameness can also be traced back to foot diseases including digital dermatitis, foot rot, or hoof lesions (Keyserlingk et al., 2009). This can happen during any lactation cycle, at any time in a cow's life. When cows are constantly standing outside of the freestall instead of lying down, they increase their chances of lameness (Fregonesi et al., 2009). Cows that are lame also have difficulty walking with the rest of the herd and will end up in the back of the milk string (Main et al., 2010), increasing their standing time and furthering the cause of lameness. Another cause of lameness is perching instead of standing fully in a stall. Even if standing time does not vary between cows for each of these behaviors, perching contributes more (Keyserlingk et al., 2012). This shows more of the importance of having quality stalls with comfortable bedding because the stall is where most lameness problems will result from.

Detecting lameness is extremely important so the proper steps can be taken to treat the cow but there are many different ways to diagnose lame cows. Most dairy farmers use visual

cues such as gait, back arching, walking speed, and weight distribution to identify lame cows on their farms (Chapnil et al., 2010). This can be very time consuming when looking at the whole herd either as the cows are going to be milked, if they're in the freestalls, or if they're in the feed bunk. A single person watching for behavioral signs of lameness could spend the entire day or more assessing cows. One way to reduce this time would be to randomly sample the herd according to Dohoo et al. (2003), but this can only be applied to herds of up to 100 cows. Main et al. (2010) suggests sampling cows as they are going to milking, but sampling the middle group of cows to get the most accurate percentage of lame cows in a herd. The healthiest cows are typically towards the front of the milk string whereas the lame cows are typically at the end (Main et al., 2010). Another method to sample cows without wasting hours watching cows going to the parlor is assessing their lying time using a Pedometer Plus tag, or similar device, which records cow lying time, how often they lie down, and approximately how long they lie down per lying bout (Mattachini et al., 2012). Since lameness is associated with lying time this can be an easier method of calculating how prevalent lameness is within a herd. Overall, there are different ways to detect lameness and there is no definite answer as to the best method, but it's important to know which cows are lame and to treat them immediately.

Foot and hock injuries are another preventable health issue that can be improved with simple cow comfort. Hock injuries can range from hair loss to lesions and even swelling with lesions. Different factors play into hock injuries on dairy farms, namely bedding type bedding depth have the biggest impact (Barrientos et al., 2013). However, foot injuries can also occur from traumatic events, namely from manure scrapers quite often (Stefanowska et al., 2000) indicating that it is more beneficial to cow health to find a different system of cleaning. When

freestalls are not maintained properly and waste is not cleaned out often enough, hock injuries increase (Barrientos et al., 2013). Freestalls should be cleaned out consistently and bedding should be maintained to have at least three kilograms per stall to see an increase in lying time, lying bouts and lying frequency (Tucker et al., 2009) which decreases the amount of time standing, decreasing hock injuries. Dairies that do not use any bedding, have only concrete, mattresses or rubber mats are at much higher risk for hock injuries than any type of bedding (Lombard et al., 2010). Sand is the ultimate bedding to avoid any sort of hock injuries according to Andreason and Forkman (2012) by being the cleanest, softest, and showing the fewest hock injuries.

Mastitis

Mastitis is a common intramammary infection that all dairies experience with high and low production cows, (Siivonen et al., 2011, Bannerman et al., 2008) and try to minimize. This disease is the result of bacteria getting into the teat and thriving. Mastitis incidence is correlated with how clean a dairy producer maintains their bedding (von Gastelen et al., 2011). If there is a lot of waste, particularly feces, there is a higher risk of being infected with mastitis because *E. coli* bacteria tend to live in feces and other organic materials (Petersson-Wolfe and Currin, 2011). There are many ways to prevent mastitis including teat dipping, pre and post-milking with an effective disinfectant, and keeping bedding clean and dry (Petersson-Wolfe and Currin, 2011). Keeping bedding clean and dry is very important to prevent bacteria growth, but also because a cow's teats are still open and vulnerable immediately after milking. If a cow becomes infected, typically their udder will become swollen and hard along with somatic cell count going above 200,000 cells/ml (Bannerman et al., 2008). Somatic cell count is used to indicate any type of

infection in the udder, not only limited to mastitis, forming a need for more information on how to diagnose mastitis. Researchers have started to look at how a cow's behavior differs when they're sick with mastitis, but healthy otherwise. When infected with mastitis, cows have been observed to spend less time ruminating and drinking, and more time standing compared to when they were healthy (Fogsgaard et al., 2012). Cows infected with mastitis in at least one of their quarters show less lying times than healthy cows (Fogsgaard et al., 2012, Siivonen et al., 2011). They also favor the quarter or quarters affected by mastitis by leaning on the opposite side when lying down, most likely due to the pain of a swollen udder (Siivonen et al., 2011). Because of the pain of mastitis, cows will not lie down as many hours which affects their comfort and health. As shown previously, lying down is an essential part of a cow's day but if the cow is prevented from doing this due to mastitis, not only will the producer lose milk from the disease, but also from problems related to less lying time. Mastitis is a curable disease, but the effects are seen over the course of the cow's life and she can often be re-infected. Because of this, every precaution should be taken to limit cases of mastitis on a dairy.

Body Condition

How much subcutaneous fat a dairy cow has is important to different health issues. Rating a cow based on how her overall body looks is referred to as body condition score or BCS and is given a numerical value of 1 through 5 in the United States. In order to predict an accurate score, one must look at different areas such as, the hook angle, posterior hook angle and tailhead depression (Bewley et al., 2008). Each end of the spectrum is the extreme with 1 being far too skinny and 5 being obese. Both of these are problematic when it comes to reproduction, specifically, calving. An ideal body score is around 3.0-3.25 prepartum (Roche et al., 2009).

When a cow is too thin, her body is not able to pull any fat stores for the extra energy she may need after calving if she is off feed resulting in ketosis (Silacci, 2014). When a cow is too obese, she may stop eating and just survive off of fat reserves leading to ketosis due to fatty liver disease (Silacci, 2014). Each of these issues is costly and time consuming to the dairy producer making preventative care the better option. Evaluating closeup cows always helps ensure that cows are going to calve in the healthiest way possible. Most dairy producers do not keep a record of body condition score because it can be quite time consuming, especially with a large dairy. There are constantly new products to help improve dairy efficiency with respect to body condition scoring. Bewley et al. (2008) took an automatic photographic approach to evaluating cows saving the dairy a lot of observation time. The body condition of a cow is one of the most important factors around calving because it is one of the most energetically demanding times during a cow's year (Roche et al., 2009). If there are complications, health and milk yield will be affected negatively (Roche et al., 2009).

Milk Yield

Lameness is one of the most common problems across dairies affecting milk yield. Farmers throw away quite a bit of money in lost milk. During the time a cow has lameness is not the only time producers are losing milk but four months before diagnosis and up to five months after treatment as well (Green et al., 2002). An individual, first lactation cow loses an average of 5.7 pounds of milk per day when afflicted with lameness (Warnick et al., 2001). A cow in her second lactation and beyond loses even more milk per day. This is a huge loss no matter what size dairy when trying to maximize milk yield from dairy cows. When cows are compared to themselves before and after a lameness event, even high producers give less milk than in the past

(Bicalho et al., 2008). A problem with seeing losses could be that dairy producers are comparing their high producing lame cows to average healthy cows and not seeing a difference in milk yield. It is important for dairy owners to understand this to see the true losses in a dairy to lameness. Hock lesions and foot diseases can increase the risk of lameness, therefore impacting milk yield.

Mastitis has been one of the most well known diseases in the dairy industry because infected cows do not produce the same quality or quantity of milk. If treated, any milk produced from quarters affected by mastitis must be thrown away. Not only are there antibiotics in the milk, but the quality is lower due to higher somatic cell count and, many times, blood in the milk. Owners have seen the direct loss of waste milk due to the intramammary infection, but the cow will also have decreased milk yield throughout her life in the infected quarter(s). Bonuses are also lost due to high somatic cell count when multiple cows are infected but unnoticed or in the early stages of the infection. Mastitis also contributes to milk loss by preventing maximum lying time due to pain in the udder. When a cow's udder is painful, it is much more difficult to put the pressure of their body weight on the area. This is a very preventable disease. By keeping freestalls and the milking barn clean, a dairy farmer will see a huge reduction in mastitis cases and an increase in milk yield.

Heat stress negatively affects milk yield because cows will have a lower dry matter intake to decrease metabolic heat produced (West, 2003). Since cows produce their own metabolic heat through eating, the more they eat the faster their internal temperature will rise. This is problematic when the outside temperature is above 25 degrees C leading the cow to decrease their feed intake and, in turn, decrease their milk yield. If cows are adequately cooled down

using shading, misters and fans, their feed intake can increase to normal capacity bringing their milk yield up to normal productivity.

Calving is one of the most stressful and energy demanding times during a cow's lactation so it is essential to make sure she has enough feed prepartum to produce the energy required and still produce milk (Roche et al., 2009). If a cow is too thin before calving, her body will not have enough energy and, most likely, not enough nutrients to help her postpartum to produce an adequate amount of milk due to ketosis (Rajala-Schultz et al., 1999). When a cow is obese prior to calving, her body will start to pull the fat reserves post-calving resulting in her liver becoming overloaded with digesting fat. This is a result of ketosis, when a cow is no longer producing her own glucose, leading to lower milk yield (Rajala-Schultz et al., 1999). For milk yield to reach its highest potential, body condition score is one of the most important factors that dairy producers should be monitoring.

Conclusion

The bottom line of all cow comfort is improving milk yield for dairies. This is why so many dairies have shelled out hard earned money for new barns, bedding, and technology, anything that may seem frivolous to a traditional dairy farmer. These new advancements are proving to help dairy farmers more than they may realize at first, but they have seen the return on their investments through increased milk yield. Cow comfort should be at the top of any dairy owner's priorities when thinking about how to improve their farm and production. All of the previous factors mentioned play a huge part in improving milk yield and well-being of dairy cattle in a successful operation.

Bibliography

Andreasen, S. N. and B. Forkman. 2012. The welfare of dairy cows is improved in relations to cleanliness and integument alterations on the hocks and lameness when sand is used as stall surface. J. Dairy Sci., 95:4961-4967

Bannerman, D.D., A.C.W. Kauf, M.J. Paape, H.R. Springer, and J.P. Goff. 2008. Comparison of Holstein and Jersey innate immune responses to *Escherichia coli* intramammary infection. J. Dairy Sci., 91:2225-2235

Barrientos, A.K., N. Chapinal, D.M. Weary, E. Galo, and M.A.G. Keyserlingk. 2013. Herd-level risk factors for hock injuries in freestall-housed dairy cows in the northeastern United States and California. J. Dairy Sci., 96:3758-3765

Bernardi, F., J. Fregonesi, C. Winckler, D.M. Veira, M.A.G. von Keyserlingk, and D.M. Weary. 2009. The stall design paradox: Neck rails increase lameness but improve udder and stall hygiene. J. Dairy Sci., 92:3074-3080

Bicalho, R.C., L.D. Warnick, and C.L. Guard. 2008. Strategies to analyze milk losses caused by diseases with potential incidence throughout the lactation: A lameness example. J. Dairy Sci., 91:2653–2661

Calegari, F., L. Calamari, and E. Frazzi. 2011. Misting and fan cooling of the rest area in a dairy barn. Int. J. Biometeorol, 56:287-295

Collier, R.J., G.E. Dahl, and M.J. VanBaale. 2006. Major advances associated with environmental effects. J. Dairy Sci., 89:1244-1253

Cook, N.B., T.B. Bennett, and K.V. Nordlund. 2004. Effect of free stall surface on daily activity patterns in dairy cows with relevance to lameness prevalence. J. Dairy Sci., 87:2912–2922

Cook, N.B., T.B. Bennett, and K.V. Nordlund. 2005. Monitoring indices of cow comfort in free-stall-housed dairy herds. J. Dairy Sci., 88:3876–3885

Chapinal, N., A. M. de Passille, and J. Rushen. 2010. Correlated changes in behavioral indicators of lameness in dairy cows following hoof trimming. J. Dairy Sci., 93:5758-5763

Drissler, M., M. Gaworski, C.B. Tucker, and D.M. Weary. 2005. Freestall maintenance: Effects on lying behavior on dairy cattle. J. Dairy Sci., 88:2381–2387

Fogsgaard, K.K., C.M. Rontved, P. Sorensen, and M.S. Herskin. 2012. Sickness behavior in dairy cows during *Escherichia coli* mastitis. J. Dairy Sci., 95:630-638

Fregonesi, J.A. and J.D. Leaver. 2002. Influence of space allowance and milk yield level on behaviour, performance, and health of dairy cows housed in strawyard and cubicle systems. Livestock Production Science, 78:245-257

Fregonesi, J.A., C.B. Tucker, and D.M. Weary. 2007a. Overstocking reduces lying time in dairy cows. J. Dairy Sci., 90:3349–3354 a

Fregonesi, J.A., D.M. Veira, M.A.G. von Keyserlingk, and D.M. Weary. 2007b. Effects of bedding quality on lying behavior of dairy cows. J. Dairy Sci., 90:5468–5472 b

Fregonesi, J.A., M.A.G. von Keyserlingk, C.B. Tucker, and D.M. Veira, D.M. Weary. 2009. Neck-rail position in the free stall affects standing behavior and udder and stall cleanliness. J. Dairy Sci., 92:1979-1985

Fregonesi, J.A., M.A.G. von Keyserlingk, and D.M. Weary. 2009. Cow preference and usage of free stalls compared with an open pack area. J. Dairy Sci., 92:5497-5502

Green, L.E., V.J. Hedges, Y.H. Schukken, R.W. Blowey, and A.J. Packington. 2002. The impact of clinical lameness on the milk yield of dairy cows. J. Dairy Sci., 85:2250–2256

Haley, D.B., J. Rushen, and A.M. de Passillé. 1999. Behavioural indicators of cow comfort: Activity and resting behaviour of dairy cows in two types of housing. Can. J. Anim. Sci., 80:257–263

Haley, D.B., A.M. de Passillé, and J. Rushen. 2001. Assessing cow comfort: Effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows. Appl. Anim. Behav. Sci., 71:105–117

Hammami, H., J. Bormann, N.M. M'hamdi, H.H. Montaldo, and N. Gengler. 2013. Evaluation of heat stress effects on production traits and somatic cell score of Holsteins in a temperate environment. J. Dairy Sci., 96:1844-1855

Husfeldt, A.W., and M.I. Endres. 2012. Association between stall surface and some animal welfare measurements in freestall dairy herds using recycled manure solids for bedding. J. Dairy Sci., 95:5626–5634

Ito, K., D.M. Weary and M.A.G. von Keyserlingk. 2009. Lying behavior: Assessing within- and between-herd variation in free-stall-housed dairy cow. J. Dairy Sci., 92:4412–4420

Jensen, M. B., L. J. Pedersen, and L. Munksgaard. 2005. The effect of reward duration on demand functions for rest in dairy heifers and lying requirements as measured by demand functions. Appl. Anim. Behav. Sci., 20:207-217

Kadzere, C.T., M.R. Murphy, N. Silanikove, and E. Maltz. 1999. Heat stress in lactating dairy cows: a review. Livestock Prod. Sci., 77:59-91

Krawczel, P.D., C.T. Hill, H.M. Dann, and R.J. Grant. 2008. Short communication: Effect of stocking density on indices of cow comfort. Am. Dairy Sci. Assoc., 91:1903-1907

Lombard, J.E., C.B. Tucker, M.A.G. von Keyserlingk, C.A. Kopral, and D.M. Weary. 2010. Associations between cow hygiene, hock injuries, and free stall usage on US dairy farms. J. Dairy Sci., 93:4668-4676

Main, D.C.J., Z.E. Barker, K.A. Leach, N.J. Bell, H.R. Whay, and W.J. Browne. 2010. Sampling strategies for monitoring lameness in dairy cattle. J. Dairy Sci., 93:1970–1978

Mattachini, G., A. Antler, E. Riva, A. Arbel, and G. Provolo. 2012. Automated measurement of lying behavior for monitoring the comfort and welfare of lactating dairy cows. Livestock Sci., 158:145-150

Norring, M., E. Mannien, A.M. de Passille, J. Rushen, L. Munksgaard, and H. Saloniemi. 2008. Effects of sand and straw bedding on the lying behavior, cleanliness, and hoof and hock injuries of dairy cows. J. Dairy Sci., 91:570-576

Petersson-Wolfe, C.S. and J. Currin. 2011. *Escherichia coli*: A practical summary for controlling mastitis. Virginia Coop. Extension, 404:1-2

Rajala-Schultz, P.J., Y.T. Grohn, and C.E. McCulloch. 1999. Effects of milk fever, ketosis, and lameness on milk yield in dairy cows. J. Dairy Sci., 82:288-294

Ruud, L. E., K.E. Boe, and O Osterast. 2010. Associations of soft flooring materials in freestalls with milk yield, clinical mastitis, teat lesions, and removal of dairy cows. J. Dairy Sci., 93:1578-1586

Siivonen, J., S. Taponen, M. Hovinen, M. Pastell, B.J. Lensink, S. Pyorala, and L. Hanninen. 2011. Impact of acute clinical mastitis on cow behavior. Appl. Anim. Behav. Sci., 132:101-106

Silacci, R. February 2014. Personal Connection: Body Condition Score.

Stefanowska, J., D. Swierstra, C.R. Braam, and M.M.W.B. Hendriks. 2001. Cow behaviour on a new grooved floor in comparison with a slatted floor, taking claw health and floor properties into account. Appl. Anim. Behav. Sci., 71:87–103

Tucker, C.B., A.R. Rogers, and K.E. Schutz. 2007. Effect of solar radiation on dairy cattle behaviour, use of shade and body temperature in a pasture-based system. Appl. Anim. Behav. Sci., 109:141-154

Tucker, C.B., D.M. Weary, and D. Fraser. 2003. Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. J. Dairy Sci., 86:521–529

Tucker, C.B., D.M. Weary, and D. Fraser. 2004. Free-stall dimensions: Effects on preference and stall usage. J. Dairy Sci., 87:1208–1216

Tucker, C.B. and D.M. Weary. 2004. Bedding on geotextile mattresses: How much is needed to improve cow comfort? J. Dairy Sci., 87:2889-2895

Tucker, C.B., D.M. Weary, M.A.G. Keyserlingk, and K.A. Beauchemin. 2009. Cow comfort in tie-stalls: Increased depth of shavings or straw bedding increases lying time. J. Dairy Sci., 92:2684-2690

Tucker, C.B., G. Zdanowicz, and D.M. Weary. 2006. Brisket boards reduce freestall use. J. Dairy Sci., 89:2603–2607

von Gastelen, S., B. Westerlaan, D.J. Houwers, and F.J.C.M. van Eerdenburg. 2011. A study on cow comfort and risk for lameness and mastitis in relation to different types of bedding materials. J. Dairy Sci., 94:4878–4888

Warnick, L.D., D. Janssen, C.L. Guard, and Y.T. Grohn. 2001. The effect of lameness on milk production in dairy cows. J. Dairy Sci., 84:1988–1997

West, J.W. 2003. Effects of heat-stress on production in dairy cattle. J. Dairy Sci., 86:2131-2144