Wayamba Journal of Animal Science – ISSN: 2012-578X; P1070-P1084, 2014
First Submitted December 10, 2014; Number 1419152024

IMPROVING COMFORT AND WELFARE TO MITIGATE STRESS IN DAIRY ANIMALS – A REVIEW

T. K. S. Rao, I. S. Chauhan, A. B. Fulsoundar, V. V. Gamit, K. Parveen
Department of LPM, Vanbandhu College of Veterinary Science and Animal Husbandry, Navsari Agricultural University, Navsari, 396 450 Gujarat

**Corresponding author:- tksrao.vet@gmail.com*

The majority of cows are now culled due to poor health and welfare. All cows should obtain adequate comfort, the design of stall and other management should be practiced to facilitate 14 hrs of lying time for each cows within a pen. Stall should be designed to allow cows to assume natural resting postures. Feed bunk management must be practiced to accommodate 3-5 hrs per day of feeding time per cow. Stocking density at stall should not go beyond 120%. Attention should be paid for welfare standard by reducing lameness, mastitis, milk fever, ketosis and improving lying time in herd. Disease related to stress/comfort include hock or neck injury, stall behavior, stall use index, stall standing index and BCS should be considered as key point to know the status of stress in cows. Behavior observation can provide clue for possible changes could be made. Stall modification can provide immense benefits to animal wellbeing, production and longevity. Stall manners while resting, eating, walking or occupying provides further information regarding comfort. Interventions are required at different aspects of management to mitigate stress and ultimately improve the production potential of herd.

Key words: comfort, lying time, stress, welfare

The behavior of dairy cows is dependent on the interaction between the animals and their physical environment. The majority of cows are now culled due to poor health and welfare. When overall culling rates are high, a farm may have difficulty in producing enough replacement heifers to maintain herd size (Orpin and Esslemont, 2010). Overstocking of barns, defined as housing more cows within pen than normal providing less than 0.6 m linear feeding space per cow (Grant and Albright, 2001). Proper housing design with improved management practices i.e., improved welfare standards affect behavior, health, longevity and performance of cows and profit of dairy farm positively. Fear or frustration in work place predisposes a cow towards the abnormal behavior, vices and risk of diseases. Behavior of cow, welfare and diseases are measure of cow comfort. Common diseases related to stress include lameness, hock or neck injury, mastitis, milk fever, ketosis and displaced abomasums. Behaviors of cow while resting, eating, walking or occupying stall will provide additional information about comfort. Positive interaction between a cow, site of housing and her caretaker lead to cow welfare, pleased employee and a productive herd (Anderson, 2001).

Behaviors of animals are good guide of welfare and level of stress (Cook et al., 2005). Attempts to improve cow comfort are aimed at increasing milk production, improved herd health, reproductive success and animal longevity. Ensuring cow comfort comes down to knowing different activities of cows during 24 hours period. In particular, the time spent lying down, the frequency of lying bouts and duration of individual bouts have been recognized as sensitive measures of comfort (Haley et al., 2000). Highest standard of care and management is required to maintain health of cow and ultimately the production. It is well established fact that cow which lie down for 12-14 hrs a day are more productive than those with lower lying times (Drissler et al., 2005; Bach et al., 2008). Increasing lying time may increase rumination, improve rumination status, increase blood flow to mammary system,

reduce stress on hoof and reduce the incidence of lameness. When a dairy animal lying down, around 22 percent more blood is flowing through her udder than when she is standing (Rolquin and Caudal, 1992). This suggests that for extra hours she lies down (maximum up to 14 hrs), produces additional milk. Improving cow comfort will alone contribute additional 1-2 liters of milk per animal per day and should not be overlooked at any cost. Lying down situation in cow additionally puts animal in rest and animals ruminates when it is lying down, the cows hoof rest and dry off, which reduces the case of lameness in herd. As the cow sits it gives more space for other cow to walk around in barn. The comfort enhances animal wellbeing and result in fewer sick cows that require treatment, improve consumer confidence in dairy product. When cow is well comfort, she uses to perform three activities properly like eating or drinking, milking and resting. On farm welfare assessment protocol include resting behaviors like duration of lying down, percentage of cows lying partly or completely outside lying area and percentage of collision during lying down recorded within 2h during a farm visit (Plesch et al., 2010). Recent research (Fregonesi et al., 2007; Hill et al., 2007; Krawczel et al., 2008) reported association between stocking density or stall availability on resting time.

In era of climate change, adjacent temperature is rising, in present context special intervention is required to cooling system to change the microclimate around the cow to improve the productivity. Summer stress particularly THI found to influence lying and standing time (Cook et al., 2007).

Guiding principles for animal welfare of World health organization specifies,

1. Critical relationship between animal health and welfare
2. Internationally recognized 'Five freedoms' provide valuable guidelines in animal wellbeing
3. Improvement in farm animal welfare and comfort can improve productivity and food safety, which leads to economic benefits.

Welfare indicators: Indicators which directly influence/ reflect the welfare status of the animals [Sejian et al., 2008]

1. Behavioral: Vices developed in farm animals indicates bad status like bar biting, tongue rolling, weaving, wind sucking
2. Physical: Problems like cut, injury, abscess formation, swelling of joint, falling of hair wool
3. Physiological: Reduced feed intake, raised cortisol in blood, immune suppression, adrenal activity, altered physiological response
4. Production: Impaired growth, reduced body weight, decrease milk yield, impaired reproduction indicates serious implications

Qualities of welfare assessment system: [Rousing et al., 2001]

1. Based on scientific knowledge and express development over time
2. Measurable at commercial farm within realistic frame work
3. Relevant decision support system for farmers

Concept of five freedoms: Free wills that are required to ensure animals in stress free environment are: (Webster, 2001)

1. Freedom from thirst and hunger
2. Freedom from discomfort
3. Freedom from pain injury and diseases
4. Freedom to express normal behavior
5. Freedom from fear and distress

Assessment of condition of farm with respect to animal comfort:

Check for standing or lying down animals (Time budget): The condition of animal can be assessed by looking at cow or buffalo in cubicle house. How many of cows or buffaloes are lying down can be observed by taking a look in barn at different time during day. It should be ideally above 85 percent. If standing sitting animal is less, then it needs critical investigation for the reason. Cow requires at least 12-14 hours of rest. Resting time increased from 11 to 14.3 hrs after two simple changes in barn i.e., longer tie chain and more straw on the rubber mats. Each hour increase in resting time resulted in a gain of 0.9-1.7 kg of milk production (Krawczel and Grant, 2009). Friend et al. (1977) reported no change in lying time until the stocking density is more than 150%. Moderate overcrowding or under-crowding

showed no significant effect on lying time (Fregonesi and Leaver, 2002; Bach et al., 2008). Conversely stocking density of 109, 120, 133 and 150% resulted in linear reduction of lying time as compared to 100% (Fregonesi et al., 2007) i.e., cow spent 13 h per day lying at 100%, which was reduced by approximately 2h when stocking density reached 150%. Similar finding was also reported by Hill et al. (2007). A greater number of aggressive interaction per hour observed with each increase in stocking density. The lying time increased significantly with increasing age and is more in winter as compared to summer season (Steensels et al., 2012). Negative correlation between milk production and lying time (Bewley et al., 2010), in early lactation as cow needs adaptation period after calving. To provide normal resting position, the resting area must provide the cow with six comfort:

1. Freedom to stretch their front legs forward
2. Freedom to lie on their side, with free space for neck and head
3. Freedom to rest their heads against their sides without hindrance
4. Freedom to rest with their legs, udders and tails on the platform
5. Freedom to stand or lie without fear or pain from neck rail, partitions or supports
6. Freedom to rest on clean, dry and soft bed.

To rise or lie down, the resting area also must provide cows with freedom of vertical, forward and lateral movement without obstruction, injury or fear. Lying standing and feeding behaviors can be interpreted by image analysis by taking restricted observation between two milking and evening hours only instead of round the clock observation (Mattachini et al., 2011). Total lying time, number of lying bouts and bout duration has been well evaluated as appropriate welfare indicators.

Daily time budget for lactating dairy cows (Grant, 2007)**:**

Activity	Time devoted to activity per day
Eating	3-5 hrs
Lying or resting	12 hrs for average cow 14 hrs for elite cow
Social interactions	2-3 hrs
Ruminating	7-10 hrs
Drinking	30 min
Management activities	2.5-3.5 hrs

Importance of resting: Reduction in resting time as a result of overcrowding is the probable explanation of reduction in performance associated with space availability. Over-stocking results in an increasing percentage of cows standing idly waiting for access to free space in barn (Hill et al., 2007). This effect becomes more pronounced between midnight and early morning, when the motivation to feed was reduced and lie down increased. Depriving cows of lying for a relatively limited period, which are similar to those reported in trial evaluating stocking density, result in cows attempting to recoup the lost resting time for the next 40 hours (Cooper et al., 2007).

Ahead of the effect on production, there are several important health related factors that are detrimental by reduced lying time. Concrete flooring results in a greater strain on the hoof when cow are forced to stand for extended period of time (Cook, 2002). Increased standing time will further worsened by softening of the hoof by the manure slurry over the surface, which leads to an increased probability of infection (Guard, 2002). High concentration of cortisol in cows reduces lying period (Munksgaard and Simonsen, 1996). Nishida et al. (2004) reported more blood flow towards uterine horn when cows were lying as compared to standing during gestation period.

Resting manners: Resting describes lying in the stall in one of the four normal resting postures i.e. long, short, narrow or wide. Long posture cows rest with their heads extended forward. In short posture, they rest their heads along their side. In narrow posture, a cow rests more on her sternum with the neck in a slight crook and the rear legs close to the body. In wide position, a cow rests more on her side with rear leg extended. Another common posture is lateral recumbency where a cow lies totally on her side with legs and head extended.

Idle standing: It describes useless positioning with all four feet in the free stall. It includes failed attempt at lying. Dairy cows standing idly in free stall marked as "pointers", spotting towards hazards in their work place.

Hesitation waltz: Some cows stand in a free stall and swing their heads repeatedly left and right is called hesitation waltz, this might be due to inadequate space for sitting in stall.

Perching: Perching show cows standing with their front feet in the stall and the rear feet in the alley. It also includes cows lying with part of their body in the stall and part in the alley. Claw horn diseases of rear feet are common in cows with perching behavior (Philipot et al., 1994). In lying cow in perching position in stall contributes to contamination of udders, teats, legs and tail which ultimately increases the risk of mastitis. Perching cows point towards the threat within the stall or lameness in cows. Lack of proper head space in stall may contribute to the perching behavior.

Diagonal standing and lying: It might be due to lack of space for standing or lying straight or lunging straight. If facing stall was occupied, the cow may show diagonal standing or lying (Anderson, 2003).

Lying backward: It describe cows resting with their heads facing the alley in free stall barns. This behavior developed due to placement of animals in ill fitted stall.

Long bout of lying or restlessness: Restless cow frequently changes position frequently from narrow (upright) to wide resting posture.

Alternate occupancy: Alternate occupancy explains cows lying in every other free stalls with an empty facing stall. It provides the cow for social space, un-blocked lunging and avoidance of a dominant cow in facing stall. The behavior primarily underlines short stalls and inadequate social space rather than dislike for facing another cow.

Herd bunching: Herd bunching in cow indicates infestation of biting stable flies and when they are heat stressed. Common signs of fly infestation indicated by twisting or tail stubs and stamping legs. Bunching around water trough or at ends of pens on summer days is common phenomenon. Lying proportion decreased as in house temperature rises with highest lying (86%) recorded during lowest observed temperature (58.8^{o}F). Cows move away from the sun and enter into shaded part of the barn. The percentage of cows standing rises as environmental temperature increases (Shultz, 1984) as standing maximizes evaporative cooling from body surfaces (Igono et al., 1987).

Rising and lying motion: It is smooth motion includes a forward lunge and retraction and a bobbing down and up of the head. Objects in the range of normal motion obstructs rising and lying. Cows manage by changing the normal bob, lunge and pendulum motion of the head and smooth motions become shuffles of the front and hind quarters.

Caudal licking or grooming: Caudal licking describes cows using their tongue to groom the fold between their udder and leg. This behavior is typical sign of floor slipperiness, as lack of this behavior is reliable indicator of floor slipperiness (Jungbluth et al., 2003). The behavior also prevents scalding between the leg and udder.

Kneeling cow syndrome (KCS): Dairy cows kneeling on their fore knees while standing upright on their hind legs. These cows defecates within the stall bed, contaminates the bedding leads to dirty udder and teats. This posture in cow might be due to challenges in their work place i.e. a low tie-rail or manger at level below the level of their feet. Cows with laminitis may also kneel by fore feet while eating.

Dog sitting behavior: Dog sitting behavior or rise like horse describes cow that sit like dogs on hind quarters with front legs extended. This behavior described as rising like horse, with the front end before the hind quarters. It may indicate injury to front leg and knee.

Frog sitting posture: Full or partial extension of both hind leg forward along the sides of recumbent body. In cattle, frog posture is an indicator of hip dislocation, rupture of the adductor muscles or paralysis of the obturator nerve.

Stereotypy: Stereotypy is excessive repetition of apparently purposeless behavior. Stereotyped behavior is abnormal

and one form of behavioral response to stressful condition.

Inspection of neck rail: The underside of the neck rail should be checked regularly. If it is shiny, it indicates that cow is contacting this every time. Anything that prevents a cow as she tries to stand up or lie down will reduce lying times. If neck rail is very close to wither it may create scar in the area. Cow stands in free stall, swinging their head to left and right, this behavior referred as "hesitation waltz". Therefore adequate dimension of chute for a particular animal is really important. Properly placed neck rail can improve lying time of cattle and buffaloes. Restlessness or frequent changing position while lying may be another sign of potential cow comfort shortcomings. Neck rail height and forward location alter stall cleanliness and standing and perching times but not lying times (Espejo, 2007). Tucker et al. (2005) recommended adjustment in the location so that cows can stand with four feet on the beds of stall with rubber filled mattresses or rubber mat.

Hock lesion: Hock lesions are very good indicator of poor cow comfort especially in zero grazing animals (Barrientos et al., 2013). On farm hock injuries is associated with a high rate of involuntary culling (Fulwider et al., 2007) and lameness due to severe hock injury is a major cause of milk loss (Bareille et al., 2003). Lesions in hock appear due to thin layer of bedding or abrasive bedding material. When animal get up she drag her back leg out from under beneath of the body, during this process bruise may appear on hock. The lesion is further aggravated, when bedding is also wet and abraded skin becomes infected. Prevalence of severe hock injuries on individual dairy farms ranges from 0 to 82% (Zaffino, 2012) and cows that are lame were nearly 1.5 times as likely to have a rigorous hock lesion as cows that are not lame. Lesion of hock should not be more than 10 percent of herd. Hock can be scored when cow are standing or lying down. Generally only one hock per cow is scored.

Hock scoring system:

Hock scores	Sign of defect	Target in herd
1	No swelling or hair missing	> 95 %
2	Bald area on hock; no swelling	< 5 %
3	Visible swelling or a lesion through the hide	-

*If we can improve low scoring area, we could have higher productivity and healthier cow.

Lameness: Lameness is second most perilous disease, major cause of culling of dairy animals after mastitis. Pain and suffering related to lameness in dairy herd make it the major welfare problems of dairy cows (Rushen et al., 2008; von Keyserlingk et al., 2009). Most of the researchers reported that zero grazing increases the risk of lameness (Haskell et al., 2006; von Keyserlingk et al., 2012). An effective method of treating lame cows is to put them on pasture (Hernandez-Mendo et al., 2007).

Lameness scoring:

Locomotion score	**Type**	**Sign of defect (Gait)**	**Target (percent) in herd**
1	Normal	Stands and walks normally with straight back	> 70
2	Mildly lame	Stands with level back and walks with arched back. Stride slightly short	< 20
3	Moderately lame	Stands and walks with arched back. Stride shorter and stop to rest.	< 10
4	Severely lame	Stands and walks with arched back. Favors certain legs. One premeditated step at a time with frequent rests.	-

European food safety authority (EFSA) permitted 10 percent prevalence of lameness in dairy herd. The prevalence of lameness is influenced by a number of variables the major one being stall usage, standing time on concrete, ration control of infectious disease and hoof trimming programs. Long term effect of laminitis and decreased body condition and reproductive performance could be even greater. Rubber alley flooring surface benefit the cow by reducing claw wear and injury compared to concrete (Cook and Nordlung, 2009). Risk factors in indoor housing required to be controlled, such as factors that increase the time that cows spend standing especially on wet, concrete floors (Bell et al., 2009) or reduced lying time (Dippel et al., 2009) appear to increase the risk of lameness.

Pattern of walking: Healthy and normal cow walking on pasture places rear foot into the position vacated by the front foot of same side (one gait). On slippery floors or in dark conditions which alters confidence, as a result cow places rear foot out side the track of the front foot, alters stride, step length and walking speed. This changed gait provides greater stability, however places greater stress on the outside claw. This could be utilized to know the level of stress in cow. Foot placement, length of stride and step and walking speed are few items of locomotion pointing to walking behavior (Telezhenko et al., 2003; Telezhenko and Bergsten, 2005). Activity and speed of walking increased on soft floors. Claw health was improved on soft, slatted floors compared to usual slatted floors (Jungbluth, 2003).

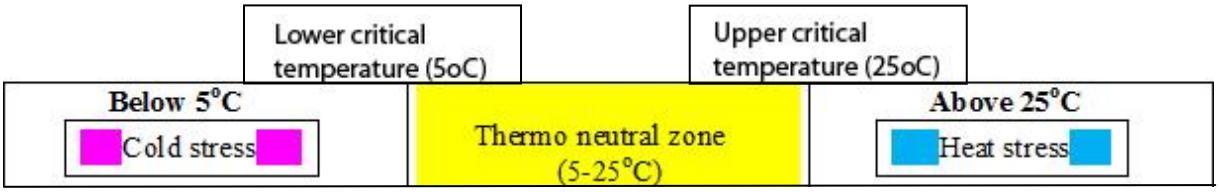
Body condition score (BCS): This will help to ensure that cow is in correct condition for each stage of her annual cycle and also appropriate dietary change could be made in order to correct any problems or deficiencies. It helps to track energy balance, comfort level and production performance of cow. BCS reduction and transition stress was diminished significantly by supplementing Vitamin E and selenium during transition stage in buffaloes (Gamit, 2014).

Effect on feeding: Overcrowding at free-stalls result in congestion at feed bunk. Many researchers worked on spatial allowance at the feed bunk of lactating dairy cows (Friend et al., 1977; DeVries et al., 2004; Huzzey et al., 2006). Reduced feed bunk space per cow less than 4 inch reduced feeding time (Friend et al., 1977). Increasing the space allotment per cow to 40 inch increases feeding time during 90 minutes of ration presentation and also decreases aggressive interaction (DeVries et al., 2004). Cows also spent more time in waiting queue for access to feeding space. One probable coping strategy observed was shift in feeding times, which may be problematic if the ration is sorted by previous cows. Recent finding showed the impact of pre-weaning growth rates on later milk production (Soberon et al., 2012) may help to bring increased attention to the importance of maintaining good calf and heifer health welfare however failure at many farms contributes to high calf mortality (Vasseur et al., 2010).

Stall uses indexes: It is an indicator of stall acceptance of cow. Optimum cow comfort will results in more than 90% free stall use index.

Stall standing index (SSI): An index that has been associated with herd-mean standing time and increased level of lameness is the stall standing index or SSI. Cow standing in stall for more time indicates high stall standing index leads to increased lameness. SSI should be calculated 2 hours before milking. The SSI should be less than 20 percent. More SSI indicates problems at farm.

Effect on rumination: Rumination improves saliva flow, providing buffers that raise rumen pH. This sequentially reduces the risk of rumen acidosis and laminitis, and enhances ruminal digestion. At lying 50-60 percent of cow in stall should be ruminating (Fournier, 2003). Batchelder (2000) reported a significantly greater percentage of cows ruminating during the day at 100% stocking density as compared to 130% (37 Vs 28%) on average 24 hrs basis, however in 118% overcrowding no difference in total time of rumination (8 h) was observed by Fregonesi and Leaver (2002). The observation is consistent with the effect of overcrowding on lying becoming evident in cows at stocking density above 120%.



Heat stress: Barn with inadequate cow cooling shows heat stress revealed by raised rectal temperature and respiratory rates. As temperature move above upper critical limit (> 25°C) cow will exhibit increased standing time in barn. Thermo-neutral zone for cow is 5 to 25°C.

Ventilation management: Adequate air exchange reduces air born bacterial numbers, humidity levels, noxious ammonia and excess heat.

Floors: Cow prefers a comfortable surface i.e. stall surface affects preference and usage (Olsson et al., 2005). Rough and slippery floor injures hoofs of dairy animals. Soft rubber or well grooved rubber belting can be used to improve the floor surface. Keeping in view optimization of cow comfort non productivity like excessive time on concrete (TOC) should be avoided by using rubber mat. Time spent in lying increased from 8.8 to 13.8 hours per day (Fregonesi et al., 2007), when wet bedding was switched to dry bedding, however it decreased by 1.7 hour when stocking rate was increased by 50 percent. Cows avoided sand bedding and preferred straw and soft rubber mats in both winter and summer as reported by Manninen et al. (2002). Cow preferred straw to soft rubber mats in winter but there was no significant difference in summer. Drissler et al. (2005) found greater lying times (2.3 hours more per day) in sand bedded stalls when sand was at the level of curb rather 5 inches below the curb. Similar finding was also reported using sand bedding by Espejo and Endres. (2007). Tucker et al. (2004) reported increased lying time (1.5 hrs/day) and decreased rate of perching with more saw dust bedding (7.5 kg Vs 1 Kg saw dust). Mowbray et al. (2003) and Tucker et al. (2004) have shown fewer hock lesions with well bedded mattresses. During heat stress, cows prefer stalls with wood savings or solid bedding over rubber mats (De Palo et al., 2006). Cows spend more time standing in front of feed bunk provided with softer flooring (Tucker et al., 2006). Cows spend significantly more time standing when close to parturition, suggesting the importance of cow comfort during this period (Huzzey et al., 2005). Prevalence of hock lesion was 31% with 2 cm bedding as compared to 80% hock lesion without bedding (de Passille et al., 2012).

Rumens fill score and Dung scoring: Rumen can be scored according to inflation at the flank region (1 to 4 score). Dung can also be scored on the basis of its consistency (1, thin liquid to 4, score thick).

Milking of dairy animals: With respect animal comfort machine milking is superior over manual hand milking. As machine milking give cow natural suckling fill due to use of negative pressure at teat cup end. Reducing milking frequency from twice to once daily during mid lactation or exclusion of a weekly milking leads to changes in behavior like lying bouts and udder tension, however the effect were temporary, therefore it is unlikely to be a significant welfare problem for dairy cow (O'Driscoll et al., 2011).

Sitting posture: Sitting posture in cow include long, short, wide and narrow. Wide posture gives better comfort to animals. Each time the cow lies down; she puts about 2/3rd of body weight on her front knee. Knee drop freely to the floor from height of 20-30 cm. It again shows the importance of bedding so the cow can painlessly lie down whenever she wants. Time required in sitting, if more than 5 minutes on an average shows problem at herd.

Stall behavior: Assessment of cow behavior and stall comfort of cow is good guide to stress and production. Resting, standing and perching times as measure of cow reaction to her stall.

In wider stall Tucker et al. (2004) observed that animal spent more time in lying down and less in standing with only front hooves

in the stall. Brisket boards make stalls less comfortable (Tucker et al., 2006). Cows prefer stalls without brisket boards and stall usage declines when boards position cows and contribute to stall cleanliness. Brisket board height of more than 15.24 cm and presence of the area behind the brisket board filled with concrete were associated with greater prevalence of lameness. Espejo (2007) observed Neck rail height and forward locaton alter stall cleanliness, standing and perching times but not lying times. Tucker et al. (2005) advises adjusting the location therefore cows can stand with four feet on the beds of stall.

Stall design:

If cows select to lie in the free stall alley rather than in the stalls may indicate that the free stalls do not provide a comfortable resting area. Frequent stall grooming can have a dramatic effect on stall usage and cleanliness of cow. Detached or broken stall dividers or structures can lead to poor stall usage, dirty cow or cow injury and entrapment. Sand bedding generally best meet the cow needs. Inadequate forward lunge space: shown by lying diagonally in stalls, dog sitting posture in cow, perching i.e., standing with front legs in the stall and rear legs in the alley. Adequate **lunge and bob** space: Cow needs 30-44 inches of space ahead of where their front knee is positioned while resting. Improperly placed neck rail identified by perching behavior. High curb height, cow may drag their teats and udders on curb or bed when entering the stall. If curb height is too low, manure from the alley may be pushed into the stalls during scraping. In addition, cow may back into stalls and lie facing outward. Narrow stall identified diagonally placed cow or come into direct contact with the stall dividers or structures while resting. The wider stall tended to be dirtier than the narrower stalls. Short stall the most obvious sign is rear end of cow hang over the edge of the curb. Stall comfort has dramatic effect on reducing laminitis in cow even on same diets (Colam-Ainsworth et al., 1989).

Improving animal comfort in and around milking: Concrete flooring in collecting and milking yard put greater impact on hoof (lameness) of dairy animals. Improving comfort to the dairy animals in this area not only help to reduce lameness but will also increase cow flow and could thereby reduce milking times. Lameness can be avoided simply by paying attention to the environment especially, to condition under foot. Concrete flooring is major risk factors for the lameness. Cow standing on concrete for up to 5 hours per day in milking parlor. There is role for rubber flooring in and around the milking parlor. Cows have more confidence when they feel sure footed while walking. Rubber flooring offers the grip of concrete grooving but is much kinder to the claws as the rough edges of grooved concrete pose a risk to claw health. The Cushioning advantage of rubber offers absorption of shock nicely. As animals are more relaxed when comfortable during standing, rubber flooring (mats and slat rubber) in the parlor may even make easier to milk cow. Lunge space and head space is essential in stall for cow comfort.

Cow comfort index (CCI): The proportion of cows lying down in stall. The advantage of the CCI is that it estimates motivation to enter a free stall and lie down and is useful for both free stall and tie stall barns. Well managed free stall system should have a CCI greater than 85 percent. It is usually highest one to two hours after milking.

Cow comfort quotient (CCQ): [Nelson, 1996]

$$CCQ = \frac{Cow\ lying\ properly}{Cows\ "in\ contact\ with\ stall"} \times 100$$

The CCQ considers those cows that made an attempt to go to a stall, lie down and get comfortable. The CCQ not include cow standing in the alleys. Cows lying half way out of stall, lying backwards, or standing with two feet in a stall are considered “in stall” cows. In well managed herd CCQ is 85-90 percent.

Normally cow should lie down 12-14 hours each day. Increased lying time also has a potential benefit for fetal growth. Getting adequate rest affect milk production in two ways:

1. Blood flow to the mammary gland improves 22 percent in cow lying as compared to standing.

2. Stall comfort reduce laminitis in cow even on the same diets.

Stall Use Index (SUI): SUI supposed to improve on CCI by taking into account more cows within a pen (Overton et al., 2003). An eligible cow means all cows not actively feeding within the pen. SUI decreased significantly above 113% overcrowding with value falling below 0.75 at the 142% stocking density.

$$SUI = \frac{Number\ of\ cows\ lying\ in\ a\ stall}{Total\ number\ of\ eligible\ cows}$$

Stall Standing Index (SSI): Monitoring cow comfort using the portion of cows standing in stall, which was associated with the total time cows, spent standing in stall (Cook et al., 2005).

Cud Chewing Index (CCI):

$$CCI = \frac{Cow\ chewing\ cud}{Cows\ "in\ stall"} \times 100$$

The 50 percent of cow lying in the stalls are chewing their cud. Herds where diets are properly designed and the cows are comfortable will have a CCI of 60-65 percent.

Cow comfort scoring system: Cow comfort can be scored in different farm and can be correlated with production level and other parameters.

Stress in cow: Common stress in cow especially in climate change scenario is heat stress was reported by Herbut and Angrecka (2012) and it is best measured by Temperature Humidity Index (THI). It is temperature and relative humidity combination to produce a sum effect.

THI = (Dry bulb temperature in ^{o}C) + (0.36 x dew point temperature at ^{o}C) + 41.2

THI level	Effect on animals
Exceeds 72	Fill heat stress
Exceed 78	Cow milk production gravely affected
If above 82	Severe stress, significant loss in milk production may die

Temperature can be mild but if humidity is high, cow starts feeling the heat.

31^{o}C and 40% RH is equivalent to 27^{o}C and 80% RH in produce heat stress of THI 78.

Stress can be observed indirectly using milk production parameters like drop in 10g milk solid per day per unit rise in THI. A drop in fat and protein percentage also reported previous to a drop in milk or milk solid is visible (Gantner et al., 2011).

Animal comfort check list:

Housing: It provides cows free access to feed and clean water round the clock i.e., eat, drink and rest whenever and wherever they choose. Cow requires 240 cm x 120 cm living space and a further 60 cm of lunging. The barn should be equipped with cooling system, fans, mist cooling etc. to minimize the heat load. Floor should be skid resistance, thick and soft to reduce injuries. Estrous activity should be easily visualized and not miss. Free stall size should be adjusted as per the animal size and create a comfortable bed preferably of wood shavings or sand. Stall comfort, lying behavior and lameness are interlinked and should all be integrated as measures of cow comfort.

Ventilation

The ventilation should be designed to prevent high humidity in winter and heat load in summer. Proper air flow is required across all cows. Poorly ventilated barn have ammonia odour, coughing, nasal discharge and moisture may be present on hair coat of animals. In the winter, barn air temperature should not be more than 5-10 degree above ambient temperature. In the spring, summer and fall, barn air temperature should be equal to ambient temperature. More ventilation required if ammonia or other odors are evident. High open sidewalls and a ridge vent opening and supplement natural ventilation with fans used to increase air flow and exchange.

Feeding

Balance ration is required for different physiological stages of animals. The feed should be provided at least 20 hours a day. The feed should be provided frequently. Feed bunk should be cleaned and refusal should be discarded at least once a day. Studies have shown that a cattle dry matter intake (DMI) is directly correlated with production. Therefore increasing DMI is a main component in increased production and proliferability. A good technique to accomplish this is promoting feed bunk management, such as frequent feed push-ups

(10-15 times a day). Ideally the cow use to eat 6-15 meals per day of 1.5 to 4 kg of DMI per meal in 20-30 minutes. So, on a whole, that would add up to about 4.5-5 hrs (19-21% of cow's day). Largest meals are taken immediately after milking, this require plenty of ration arrangement just after milking.

Milking

Total milking turn time is important factor contributing to cattle and buffalo comfort. Total milking turn time starts when cow are pushed to the parlor and ends when the last cow gets back to the pen. The total milking turn time should be less than 3 hours (13% of total time) per day, regardless of no. of milking takes place a day. Increase in this time takes away from a cow's other activities, like eating and socializing which ultimately decreases milk production and heat expression. Sound milking practices also include proper pre-milking stimulation, followed by post-milking teat dip.

Effect on milk quality: Milk quality affected by stress especially the overcrowding (Hill et al., 2007). Milk fat percent was reduced by approximately 0.2% at 142% overcrowding as compared to 100%. Somatic Cell Count (SCC) apt to increase in overcrowding above 113%. Number of incidents of clinical mastitis during lactation period observed 2.5 fold increase when overcrowding was 142% as compared to 100% (Krawczel et al., 2008).

Cow Hygiene/ Cleanliness: It is an indicator of characteristics of the environment in which animals are kept. Dirty cow are greater risk of developing intra mammary infection. Linear Somatic cell score increased as the score for udder, legs and the composite score increased. Hygienic score of leg and udders are highly correlated. Animal hygienic score vary from 1 (Very clean) – 4 (Dirty).

Lock up:

Lock up time is essential for different reasons on a farm like heat detection, vaccination, A.I., general examination etc. Total time spent locked up or retained for management purpose per day should not exceed 1.5 hours (6%) per day. Other activities especially feeding is affected if lock up period prolonged.

Socializing

Socializing means walking around and interacting with other animals around her. This includes grooming, exercise, licking and expression estrus behavior. On an average time spent in socialization is 1.5 hrs (6%) of the day.

Drinking

Water consumption is crucial component of milk production. Cattle use to spend 1 hrs (4%) of the day in drinking fresh water. 3 inches linear space required per animal for drinking.

Overstocking

Overstocking leads to competition for resources which affect natural behavior of cow. The overstocking will dictate the extent that natural feeding, resting and rumination are inhibited. Aggressive interaction per hour occurred with each increase in stocking density. Overstocking decreases milk production. Somatic cell count (SCC) in milk increase as overcrowding increase above 113 percent. Stocking density at the free stalls should not exceed 120 percent (Krawczel and Grant, 2009). Rumination time was reduced by 25 percent in overcrowded group.

The following question may be asked to assess and evaluate the comfort of dairy animals

1. Animal appear relaxed, comfortable and content when standing or sitting in stalls
2. The stalls used equally
3. Animal lie backward in stall, alleys
4. Animal stands half in, half out of stall
5. Animal stand in stall in an angular fashion
6. All stall are not used equally
7. At resting time, more than 20-30 percent standing in the stall
8. Animals udder dirty
9. Animal not bears weight on all four legs

***** If serial no. 1 and 2 is NO and other YES, identifies the areas that need improvement.

Managing pain to augment cow comfort:

Cow comfort initiative focus on environmental aspects of cow comfort, but there are pain management technique that can lessen animal discomfort.

Overall target for cow comfort in herd:

Parameters	Target
Time budgets	More than 12 hrs resting time
Cow comfort index	More than 85 percent, 1-2 hrs post milking
Stall standing index	Less than 20 percent, 2 hrs pre milking
Rumination time	More than 50 percent of resting cow
Lameness score	More than 70 percent completely normal
Hock score	More than 95 percent without any swelling or hair missing
Floors	Confident traction without hoof wear
Heat stress	Pulse rates less than 70 bpm, rectal temperature less than 102 degree
Fly control	No bunching during summer

Pain inducing factors: Pain inducing factors include **Infectious** like mastitis, metritis, diarrhea, pneumonia, **surgical** procedures like dehorning, castration, tail docking, laceration etc, **others** like fractures, strain, sprain, dislocation etc.

Pain management: Pain management in dairy animals includes use of drugs for controlling drugs. Pain management by drugs includes the use of anesthetics, Non Steroidal Anti Inflammatory drugs and Sedatives. Pain medication should be administered at least 30 minutes before an incision is made to decrease pain associated with surgical procedure.

CONCLUSION

Stress mitigation in cow not only include environmental comfort, but also protocol that can ease or possibly alleviate pain in dairy animals. Assessment of condition of farm with respect to animal comfort includes mainly lying time, lesions, lameness, rumination time, status of ventilation, condition of floor and stall design. Cow comfort can be improved dramatically through modification of existing free stalls. Observing cow behavior can provide clues for evaluating what changes could be made. Different index are used to assess the comfort of animal i.e., cow comfort index. Cow comfort improvements achieved through stall modification can provide immense benefits to animal wellbeing, milk production and cow longevity, all together minimizing farmers' frustration and stress. Clear animal welfare standards combined with efficient use of inputs allow producers to compare themselves with their peers will definitely deal with such problems.

REFERENCES

1. Anderson, N . G. (2001) Time lapse video opens our eyes to cow comfort and behavior. Proc. American Assoc Bovine Practitioner Conference 34, 35-42.
2. Anderson, N . G. (2003) Observation on dairy cow comfort: diagonal lunging, resting, standing and perching in free stalls. Proc. 5th International Dairy Housing Conference ASAE, 26-35.
3. Bach, A., Valls, A., Solan, & Torrent, T. (2008) Association between nondietary factors and dairy herd performance. J. Dairy Sci. 91, 3259-3267.
4. Bareille, N., Beaudeau, F., Billon, S., Robert, A. & Faverdin, P. (2003) Effects of health disorders on feed intake and milk production in dairy cows. Livestock Production Science 83, 53-62.
5. Batchelder, T. L. (2000) The impact of head gates and overcrowding on production and behavior patterns of lactating dairy cows. Pages 325-330 in Dairy Housing and Equipment Systems. Managing and Planning for Profitability. NRAES Publ. 129. Camp Hill, PA.
6. Barrientos, A.K., Chapinal, N., Weary, D.M., Galo, E. & von Keyserlingk, M.A.G. (2013) Herd-level risk factors for hock injuries in freestall-housed dairy

cows in the northeastern United States and California. Journal of Dairy Science 96 (6),3758–3765.
7. Bell, N.J., Bell, M.J., Knowles, T.G., Whay, H.R., Main, D.J. & Webster, A.J.F. (2009) The development, implementation and testing of a lameness control programme based on HACCP principles and designed for heifers on dairy farms. Veterinary Journal 180, 178-188.
8. Bewley, J. M., Boyce, R. E., Hockin, J., Munsgaard, L., Eicher, S. D., Einstein, M. E. & Schutz, M. M. (2010) Influence of milk yield, stage of lactation and body condition score on dairy cattle lying behavior measured using a automated activity monitoring sensors. J. Dairy Res. 77,1-6.
9. Colam-Ainsworth, P., Lunn, G. A., Thomas, R. C. & Eddy, R. D. 1989. The Veterinary Record, 2 Dec 89, pp. 563-576. Minnesota Dairy Initiatives: Worksheet-9.
10. Cook, N. B. (2002) The influence of barn design on dairy cow hygiene, lameness and udder health. Pages 97-103 in Proc. 35th Annu. Conf. Am. Assoc. Bovine. Pract., Stillwater, OK.
11. Cook, N. B., Bennett, T. B. & Nordlund, K. V. (2005) Monitoring indices of cow comfort in free-stall-housed dairy herds. J. Dairy Sci 88, 3876-3885.
12. Cook, N. B., Mentink, R. L., Bennett, T. B. & Burgi, K. (2007) The effect of heat stress and lameness on time budgets of lactating dairy cows. J. Dairy Sci. 90, 1675-1682.
13. Cook, N. B. & Nordlund, K. V. (2009) The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics: Review. The Veterinary Journal 179, 360-369.
14. Cooper, M. D., Arney, D. R. & Phillips, C. J. C. (2007) Two or four hour lying deprivation on the lying behavior of lactating dairy cows. J. Dairy Sci. 90, 1149-1158.
15. De Palo, P., Tateo, A., Zezza, F., Corrente, M. & Centoducati, P. (2006) Influence of free-stall flooring on comfort and hygiene of dairy cows during warm climatic conditions. J. Dairy Sci. 89 (12), 4583-4595.
16. de Passillé, A. M., J. Rushen, D. Vora, J. Gibbons, E. Vasseur, & G. Charlton . (2012) Measuring up: Research project into improving cow longevity also benchmarks key aspects of adherence to Code of Practice recommendations. The Milk Producer. October 2012. Pp. 34-36.
17. De Vries, T. J., von Keyserlingk, M. A. G. & Weary, D. M. (2004) Effect of feeding space on the inter-cow distance, aggression and feeding behavior of free-stall housed lactating dairy cows. J. Dairy Sci. 87, 1432-1438.
18. Dippel, S., Dolezal, M., Brenninkmeyer, C., Brinkmann, J., March, S., Knierim, U. & Winckler, C. (2009) Risk factors for lameness in cubicle housed Austrian Simmental dairy cows. Preventive Veterinary Medicine 90, 102-112.
19. Drissler, M., Gaworski, M., Tucker, C. B. & Weary, D. M. (2005) Freestall maintenance effects on lying behavior on dairy cattle. J. Dairy Sci. 88, 2381-2387.
20. Espejo L. A. & Endres, M. I. (2007) Herd-level risk factors for lameness in high-producing Holstein cows housed in freestall barns. J Dairy Sci. 90(1), 306-314.
21. Fournier, A. (2003) Are your cows obtaining enough vitamin ‘R’ [rest]?. Producteur de Lait Quebecois 24, 18-19.
22. Fregonesi, J. A. & Leaver, J. D. (2002) Influence of space allowance and milk yield level on behavior, performance and health

of dairy cows housed in straw yard and cubicle systems. Livest. Prod. Sci. 78, 245-257.
23. Fregonesi, J. A., Veira, D. M., Von Keyserlingk, M A. G. & Weary, D. M. (2007) Effect of bedding quality on lying behavior of dairy cows. J. Dairy Sci. 90, 5468-5472.
24. Friend, T. H., Polan, C. E. & McGilliard, M. L. (1977) Free stall and feed bunk requirements relative to behavior, production and individual feed intake in dairy cows. J. Dairy. Sci. 60, 108-116.
25. Fulwider, W.K., Grandin, T., Garrick, D.J., Engle, T.E., Lamm, W.D., Dalsted, N.L. & Rollin, B.E. (2007) Influence of free-stall base on tarsal joint lesions and hygiene in dairy cows. Journal of Dairy Science 90, 3559-3566.
26. Gamit, V. V. (2014) Effect of managemental interventions on production performances and udder health of transition surti buffaloes. M.V.Sc. Thesis, Navsari Agricultural University, Navsari 396 450 Gujarat, India.
27. Gantner, V. (2011) Temperature humidity index values and their significance on daily production of dairy cattle. Mljekarslvo 61 (1), 56-63.
28. Grant, R. (2007) Taking advantage of natural behavior improves dairy cow performance. Pages 225-236 in Proc. Western Dairy Management Conf., Reno, NV.
29. Grant, R. J. & Albright, J. L. (2001) Effect of animal grouping on feeding behavior and intake of dairy cattle. J. Dairy Sci. 84, E156-E163.
30. Guard, C. (2002) Environment risk factors contributing to lameness in dairy cattle. Pages 271-277 in Dairy Housing and Equipment System, Managing and Planning for Profitability. Natural Resource, Agriculture and Engineering Service Publ. 129 Camp Hill, PA
31. Haley, D. B., Rushen, J. & de Passille, A. M. (2000) Behavioral indicators of cow comfort: Activity and resting behavior of dairy cows in two types of housing. Can J. Anim. Sci. 80, 257-263.
32. Haskell, M.J., Rennie, L.J., Bowell, V.A., Bell, M.J. & Lawrence, A.B. (2006) Housing system, milk production, and zero-grazing effects on lameness and leg injury in dairy cows. Journal of Dairy Science 89, 4259-4266.
33. Herbut, P. & Angrecka, S. (2012) Forming of temperature-humidity index (THI) and milk production of cows in the free-stall barn during the period of summer heat. Animal Science Papers and Reports 30 (4), 363-372.
34. Hernandez-Mendo, O., von Keyserlingk, M.A.G., Veira, D.M. & Weary, D.M. (2007) Effects of Pasture on Lameness in Dairy Cows. J. Dairy Sci. 90, 1209-1214.
35. Hill, C. T., Krawczel, P. D., Dann, H. M., Ballard, C. S., Hovey, R. C. & Grant, R. J. (2007). Effect of stocking density on the short-term behavior of dairy cows. J. Dairy Sci. 90 (Suppl. 1), 244.
36. Huzzey, J. M., von Keyserlingk, M. A. G. & Weary, D. M. (2005) Changes in feeding, drinking and standing behavior of dairy cows during the transition period. J Dairy Sci. 88 (7), 2454-2461.
37. Huzzey, J. M., De Vries, T. J., Valois, P. & von Keyserlingk M. A. G. (2006) Stocking density and feed barrier design affect the feeding and social behavior of dairy cattle. J. Dairy Sci. 89, 126-133.
38. Igono, M. O., Johnson, H. D., Steevens, B. J., Krause, G. F. & Shanklin, M. D. (1987) Physiological, productive and

economic benefits of shade, spray and fan system versus shade for Holstein cows during summer heat. J. Dairy Sci. 70, 1069-1079.
39. Jungbluth, T., Benz, B. & Wandel, H. (2003) Soft walking areas in loose housing system for dairy cows. Proc 5th International Dairy Housing Conference, ASAE : 171-177.
40. Krawczel, P. & Grant, P. (2009) Effect of cow comfort on milk quality, productivity and behavior. NMC Annual Meeting Proceedings.
41. Krawczel, P. D., Hill, C. T., Dann, H. M. & Grant, R. J. (2008) Effect of stocking density on indices of cow comfort. Journal of Dairy Science 91 (5), 1903-7. doi 10.3168/jds.2007-0520.
42. Manninen, E., de Passille, A. M., Rushen, J., Norring, M. & Soloniemi, H. (2002) Preferences of dairy cows kept in unheated buildings for different kind of cubicle flooring. Appl Anim Behav Sci. 75, 281-292.
43. Mattachini, G., Riva, E. & Provolo, G. (2011) The lying and standing activity indices of dairy cows in free stall housing. Applied Animal Behavior Science 129, 18-27.
44. Mowbray, L., Vittie, T. & Weary, D. M. (2003) Hock lesion and free stall design: Effect of stall surface. Proceedings 5th International Dairy Housing Conference, ASAE. 288-295.
45. Munksgaard, L. & Simonsen, H. B. (1996) Behavioral and pituitary adrenal-axis response of dairy cows to social isolation and deprivation of lying down. J. Anim. Sci. 74,769-778.
46. Nelson, A. J. (1996) On-farm nutrition diagnostics. Pages 76-85 in Proc. 29th Annu. Conf. Am. Bovine Pract., San Diego, CA. Am. Assoc. Bovine Pract., Rome, GA.
47. Nisshida, T., Hosoda, K., Matsuyama, H. & Ishida, M. (2004) Effect of lying behavior on uterine blood flow during the third semester of gestation. J. Dairy Sci. 87, 2388-2392.
48. O'Driscoll, K., Gleeson, D., O'Brien, B. & Boyle, L. (2011) Does omission of a regular milking event affect cow comfort. Livestock science 138, 132-143.
49. Olsson, J., Magnusson, M. & Ventorp, M. (2005) The effect of the passage flooring in cubicle houses on the behavioral time-budget of dairy cows. Proc International Soc Anim Hygiene 2, 140.
50. Orpin, P. G. & Esslemont, R. J. (2010) Culling and wastage in dairy herd: An update on incidence and economic impact in dairy herds in the UK. Cattle Practice 18, 163-172.
51. Overton, M. W., Moore, D. A. & Sischo, W. M. (2003) Comparison of commonly used indices to evaluate dairy cattle lying behavior. Pages 125-130 in Proc. 5th Int. Dairy Housing Conf., Fort Worth, TX. Am. Soc. Agric. Biol. Eng., St. Joseph, MI
52. Philipot, J. M., Pluvinage, P., Cimarosti, I., Sulpice, P. & Bugnard, F. (1994) Risk factors of dairy cow lameness associated with housing conditions. Vet Research 25 (2-3), 244-248.
53. Plesch, G., Broerkens, N., Laister, S., Winckler, C & Knierim, U. (2010) Reliability and feasibility of selected measures concerning resting behavior for the on farm welfare assessment in dairy cows. Applied Animal Behavior Science 126, 19-26.
54. Rolquin, H. & Caudal, J. P. (1992) Annala of Zootechnology 41,101. Minnesota Dairy Initiatives: Worksheet -9.
55. Rousing, T., Bonde, M. & Sorenson, J. T. (2001). Aggregating welfare indicators

into an operational welfare assessment system: a bottom-up approach. Acta Agric. Scan. A: Anim. Sci. Suppl. 30, 53-57.
56. Rushen, J., de Passillé, A. M., von Keyserlingk, M. & Weary, D. M. (2008). The Welfare of Cattle. Springer, Dordrecht, The Netherlands. pp303.
57. Sejian, V. Sanyal, S., Das, P. K., Ghosh, P. R., Sivakumar, B. & Pandiyan, G. D. V. (2008). Effect of unilateral adrenalectomy on the blood biochemistry of black Bengal goat (Capra hircus). Turk. J. Vet. Anim. Sci. 32, 249-254.
58. Shultz, T. A. (1984) Weather and shade effects on cow corral activities. J. Dairy Sci.67, 868-873.
59. Soberon, F., Raffrenato, E., Everett, R.W. & Van Amburgh, M.E. (2012). Preweaning milk replacer intake and effects on long-term productivity of dairy calves. Journal of Dairy Science 95, 783-793.
60. Steensels, M., Bahr, C., Daniel, B., Halachmi, I., Antler, A. & Maltz, E. (2012). Lying pattern of high producing healthy dairy cows after calving in commercial herds as affected by age, environmental conditions and production. Applied Animal Behavior Science 136, 88-95.
61. Telezhenko, E. V., Bergsten, C. & Manske, T. (2003) Cow locomotion on slatted and solid floors assessed by trackway analysis. Proc. 12th International Symposium on lameness of ruminants, Orlando, FL, USA. 417-419.
62. Telezhenko, E. & Bergsten, C. (2005). Influence of floor type on the locomotion of dairy cows. Appl. Anim. Behav. Sci.93 (3-4), 183-197.
63. Tucker, C. B. & Weary, D. M. (2004) Bedding on geotextile mattresses: how much is needed to improve cow comfort? J Dairy Sci. 87(9), 2889-2895.
64. Tucker, C. B., Weary, D. M. & Fraser, D. (2005) Influence of neck- rail placement on free-stall preference use and cleanliness. J Dairy Sci. 88(8), 2730-2737.
65. Tucker, C. B., Zdanowicz, G. & Weary, D. M. (2006) Brisket boards reduce freestall use. J Dairy Sci. 89(7), 2603-2607.
66. Vasseur, E., Borderas, F., Cue, R.I., Lefebvre, D., Pellerin, D., Rushen, J., Wade, K.M. & de Passille, A.M. (2010) A survey of dairy calf management practices in Canada that affects animal welfare. Journal of Dairy Science 93, 1307-1315.
67. von Keyserlingk, M.A.G., Barrientos, A., Ito, K., Galo, E. & Weary, D.M. (2012). Benchmarking cow comfort on North American frees tall dairies: Lameness, leg injuries, lying time, facility design, and management for high-producing Holstein dairy cows. Journal of Dairy Science 95, 7399-7408.
68. von Keyserlingk, M.A.G., Rushen, J., de Passillé, A.M. & Weary, D.M. (2009). Invited review: The welfare of dairy cattle-key concepts and the role of science. Journal of Dairy Science 92, 4101-4111.
69. Webster, A. F.J. (2001) Farm animal welfare: the five freedoms and the free market. Vet. J. 161, 229-237.
70. Zaffino, J. C. (2012) An evaluation of hock, knee, and neck injuries on dairy cattle in Canada . M Sc Thesis, University of Guelph.

