The Impact of Tie Stall Facilities on Dairy Welfare and the Broader Dairy Industry

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Abstract

The roster of standard operating procedures and recommended practices on dairy farms is constantly evolving, shaped by new technology, science and practical experience. This evolution is increasingly driven by measurable animal welfare outcomes and societal pressures about what is acceptable by consumers. Consumer concerns and questions about management practices need to be addressed using science and ethics. Our objective is to discuss the concern of permanent tethering of lactating cattle, the demographic of dairy farms that utilize tie stall systems, best management practices (BMP) for tie stalls, how tie stalls compare to other housing options based upon animal welfare indicators as well as the

economic and societal impact of transitioning away from tie stall facilities. In 2016, the dairy industry was presented with customer concern around tie stalls for lactating cattle and how they potentially limit freedom of movement. The National Dairy FARM Animal Care Program, administered by the National Milk Producers Federation, developed a task force to address the customer concern, as well as to develop BMP for tie stalls. A literature review was conducted to evaluate current tie stall design recommendations and reported rates of welfare indicators. Based on research available, tie stall facilities that implement BMP provide equal opportunities for sound welfare for lactating dairy cattle in comparison to those housed in other types of facilities. Reported disease incidence, mortality, BCS, hygiene and locomotion score of 1 are similar in tie stall and freestall systems. Tie stalls tend to have a greater percentage of cows with a hock & knee score and hygiene score of 3 as compared to freestall facilities. More research is needed to evaluate the type and age of facility, environmental control, lameness rates, disease risk, udder health, and welfare of cows that are housed in tie stalls and compare these values to those obtained in other housing systems. Results of this literature review will be used to enhance BMP in the next revision of the animal care standards for the FARM Program which are scheduled to be implemented on dairy farms in the United States starting in 2020.

Primary Concerns

Housing facilities for cattle should provide good air quality, a dry comfortable resting place, easy access to quality feed, clean water, and confident footing. Tie stall barns and stanchion barns have been used for decades to house dairy cattle in the United States and abroad. These dairy barns provide a designated stall for each cow and sometimes young stock. Animals in a tie stall are tethered, while those in stanchion barns are restrained in a head yoke while they rest, milk and eat.

Alternatively, dairy cattle housing facilities such as freestall barns and bedded pack barns allow cows to move around a pen within a barn to eat, drink and rest whenever and wherever they like. In these barns, cows do not have a designated stall to lie down, or an individual feeding or watering station. Cows are moved from these barns to a milking parlor. Tiestall, stanchion, freestall, and bedded pack barns have their advantages and disadvantages for cow comfort, welfare, cost, labor requirements, and health monitoring.

The primary concern voiced by consumer groups regarding tie stall and stanchion housing for dairy cattle, is the associated restriction of movement, similar to the concerns previously voiced about tethering sows in swine units.

In many dairy herds, cattle in tie stall barns are released into a paddock or exercise lot for a few hours each day, while the barn is cleaned, re-bedded and feed is delivered. Some operations are set up so that cattle are able to graze pasture for a portion of the day. In the United States, 73.1% of tie stall operations, representing 67.5% of the cows housed in tie stall facilities, allowed pasture access for their lactating herd, while 85.2% of operations, representing 83.9% of dry cows housed in tie stalls, allowed non-lactating cows pasture access (USDA, 2016).

Advantages of tie stall and stanchion housing systems quote two main advantages compared to other forms of housing.

1. Less direct competition for a place to rest, eat and drink; since each cow is provided her own stall, with a feed manger and access to water.
2. Improved detection of the sick – through intake monitoring since each cow's feed is only accessible (for the most part) by that cow.

Other advantages include the potential for decreased facility cost, ability to control the cow's environment, safety, and different labor needs as compared to other dairy housing facilities.

Proponents of exercise identify two main benefits for tie stall housed dairy cows; improved health and improved behavioral freedom. Popescu et al. (2013) and Regula et al. (2004) noted a significant reduction in lameness in tie stall herds and Loberg et al. (2004) showed an improvement in claw conformation and heel horn erosion with regular access to outside exercise. Keil et al. (2006) and Gustafson et al. (1993) found outdoor access improved hock abrasions. Kiel et al. (2006) stressed the importance of the duration of outdoor access to observe a positive effect, recommending a minimum of 50 hours of outdoor access within a 4-week period, equivalent to 1.5 to 2 hours per day. Gustafson et al. (1993) observed reduced risk for illness with daily exercise. Additionally, it has been noted that cows had an improved ability to groom, improved socialization and movement while untethered (Veissier et al., 2008).

While it is accepted that restriction of movement poses a potential stress to the cow, the assessment of welfare involves aspects of evaluating the affective state of the cow, the importance of natural living and the biological functioning of the cow. The studies cited above suggest outside exercise provides some behavioral freedom and may improve certain aspects of health. However, it can also be argued that the design of the housing has a significant impact on injury and lameness, and that forcing untethered exercise in some situations may increase the risk of injury.

The goal of this review paper is to address the welfare, health, cost, labor, ethical and societal impacts of tie stall and stanchion housing for lactating dairy cattle. Specifically, this review will examine the health and performance of tie stall or stanchion housed herds compared with herds housed and managed in alternative systems, to address the concern that tie stall or stanchion housed cows have poorer welfare than cows in other systems. The goal of this paper is to identify best management practices for the operation of tie stall facilities for lactating cattle to ensure enhanced well-being.

Demographics

To understand the impact of tie stall and stanchion facilities in the US it is necessary to estimate the number of dairy farm operations that use tie stalls and the number of dairy animals that are housed in tie stalls.

USDA- National Agricultural Statistics Service (NASS) reported 9,208,000 dairy cows on farm in 2014. In addition, an approximately equal number of dairy youngstock (birth to first calving) were present.

Herd Size and number of US Dairy Operations

USDA's-National Animal Health Monitoring System (NAHMS) recognizes four farm size categories, by number of cows, as follows: Very small (< 30), small (30-99), medium (100-499), large (≥ 500). These herd size breakdowns will be utilized throughout the paper.

The most current Census of Agriculture conducted in 2012 by USDA-NASS reported the percent inventory (of dairy cows) to be 1.6% in very small herds, 15.6% in small herds, 24.3% in medium size herds, and 58.5% in large herds (Table 1; Figure 1; USDA 2014). The number of cows in large herds grew from 54.9% in 2008 to 58.5% in 2012 (Figure 2). If that same trend continued, it can be estimated that approximately 62% of US dairy cattle inventory are in large herds (> 500 cows) in 2016. Given the percent inventory in 2012 (9,236,000 dairy cows; USDA, 2014), that means that 147,776 cows were in very small herds, 1,440,816 cows were in small herds, 2,243,348 cows were in medium herds and 5,403,060 cows were in large herds.

In 2013, the number of licensed dairy herds was 46,975 (USDA, 2015). If the number of dairy cows in each of the four categories is approximately in the middle of the range (15 cows in very small herds, 65 in small herds, 300 in medium herds, and 800 in large herds), then the estimated total number of dairy farms in the four categories would be 9,849 (very small), 22,159 (small), 7,479 (medium), and 6,752 (large). Collectively this is 46,238 dairy farms. This

number is close to official number of dairy operations in 2013. In 2016, the total number of licensed dairy herds decreased to 41,809.

In 2014, 38.9% of all operations (~18,000 operations) housed their lactating cows primarily in tie stall or stanchion facilities (Table 2; USDA, 2016). In US surveys, tie stall and stanchion barns have been grouped together as a housing type, so the percentage of herds that use stanchion housing is unknown. For the four size categories, these percentages were 42.6% (4,195 very small farms), 58.1% (12,874 small farms), 12.1% (905 medium size farms) and 1.2% (81 large farms). In the western region (CA, CO, ID, TX and WA), 3.2% of operations housed their lactating cows in tie stalls or stanchions while in the Eastern region (IN, IA, KY, MI, MO, NY, OH, PA, VT, VA and WI), 42.2% of operations housed their lactating cows in a tie stall or stanchion barn (Table 3).

In 2014, on average 18.2% of all operations (8,415 farms) housed their dry cows primarily in tie stalls or stanchions (USDA, 2016). For the four size categories, these percentages were 32.6% (very small), 24.8% (small), 4.3% (medium) and 0.0% (large). All operations that reported housing dry cows in tie stalls were in the Eastern region of the US.

Tie stalls or stanchions were the primary housing type used for pre-weaned heifers (typically birth to 2 months), on 9.7% (very small), 7.1% (small), 0.6% (medium), and 0.3% (large) of operations (USDA, 2016). Overall, 5.2% of operations housed pre-weaned heifers in tie stalls or stanchions. For weaned heifers, the percentage of operations in these 4 size categories were 13.1%, 6.5%, 1.8%, and 0.0%. Independent of herd size, 5.7% of operations housed weaned heifers in tie stalls or stanchions.

Milk Production

The percent of total milk production in 2012 in the four herd size categories was 1.0% (very small), 12.7% (small), 23.3% (medium), and 63.0% (large), respectively (Table 1).

Best Management Practices

Before detailing Best Management Practices (BMP) for tie stall and stanchion facilities it is important to differentiate between the two systems.

Stanchions

In a stanchion, the cow is restrained to an individual stall in a yoke which consists of two rails that close around the cow's neck after she enters a stall. Cows are not able to enter and leave

the stall at will. A stanchion controls the position of the cow in the stall and allows for improved handling. Stanchions have some significant welfare issues, including:

1. Potential trauma to the shoulder area of cattle.
2. Failure to allow the cow to groom herself in the stall.
3. Failure to allow the cow to rest in the 'closed' position, with the head curled around next to the chest.
4. Failure to allow the normal rising movements of the head and neck, which is particularly a problem for lame cows.

With these welfare concerns, stanchion housing with yokes can no longer be recommended for permanent housing of cattle, however, they may remain an acceptable solution for the short-term handling and milking of cattle.

Tie stalls

In comparison to stanchions, tie stalls allow the animal more freedom as the cow is restrained to an individual stall by a neck collar attached to the stall by a chain. Cattle are not able to enter and leave the stalls at will. Being restrained by only a neck chain, allows her the ability to lunge, and more freedom of movement as compared to a stanchion system.

As stanchion housing systems cannot be recommended, the remainder of this paper will focus on BMP for tie stall systems.

Tie stall Design

There are currently three, non-biased, on-line resources publicly available to assist US dairy producers to make design decisions for tie stall housing:

1. OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs) guidelines at http://www.omafra.gov.on.ca/english/livestock/dairy/facts/tie stalldim.htm;
2. Penn State Extension at http://abe.psu.edu/extension/idea-plans/dairy/tie-stall-barns;
3. The Dairyland Initiative at https://thedairylandinitiative.vetmed.wisc.edu/.

Aspects of design that are critical to the comfort of the cow in a tie stall include:

- The stall surface (e.g., concrete, rubber mats, sand),
- The lunge area (length of chain from neck to rail and area in front of the cow),

- The resting space (the width and length of the stall platform, stall dividers),
- The location of the waterer,
- The use of the cow trainer.

Stall Surface

Cows in a tie stall facility spend more time in an individual stall, as compared to a cow in a freestall system. Because of this, the stalls must provide a comfortable bed to stand and lie down upon since they are tethered and cannot walk away from an uncomfortable stall.

Sand or other deep bedded material are considered the optimal stall surface. Thick rubber crumb filled, air-filled, or foam filled mattresses are other acceptable alternatives, however, sparsely bedded concrete or a thin rubber mat (less than one-inch thickness) with a small amount of organic bedding cannot be considered an acceptable stall surface for a dairy cow, regardless of housing type.

There is a lower prevalence of lameness in cows bedded with sand in tie stalls as compared to mat or mattress bedding surfaces (Cook, 2003). There is an increased risk for carpal (knee) swellings on concrete and reduced resting time compared to a rubber mat (Rushen et al., 2007).

Some tie stall beds have the potential to be converted to deep, loose bedding, using a bedding retainer fixed to the rear of the stall platform. The manure gutter and barn cleaner must be adapted for the use of sand and the successful removal of manure from the barn if that bedding material is chosen (Figure 3).

Lunge Space

Lunge space is the room needed for normal lying and rising motions. It extends forward, downward and upward for head lunge, and bob, vertically and forward for standing and laterally for hindquarter movements. Knowledge of lunging space is needed to properly size the opening at the front of tie stalls, position the tie rails, and choose the shape and dimensions of stall dividers.

It has been observed that a mature Canadian Holstein cow uses 102 X 52 inches of living space, and another 16 to 24 inches of forward space for lunging motions. When rising or lying normally, a mature Holstein uses about 10 feet of space measured from her tail to her most forward lunge distance.

A tie chain is used to confine the animal to her stall, but allows for ease of lunging, resting in the head back position and grooming. It is currently recommended to use a higher tie rail and longer neck chains to provide more freedom of movement to animals in a tie stall facility. Utilizing a short neck chain can be restrictive to the rising and lying movement of the animal and is not recommended.

Longer neck chains have been shown to reduce the risk for hock lesions (Zurbrigg et al., 2005; Nash et al., 2016; Bouffard et al., 2017) as well as neck, and knee injuries (Bouffard et al., 2017; Figure 4). However, neck chain length should be no longer than the distance from the lower edge of the tie rail to the top of the feed curb. This will prevent the cow's front foot from becoming tangled. To have a longer chain, the tie rail must be located higher and further forward (Figure 5). For mature Holstein cows, it is recommended to position the tie rail 48 inches (122 cm) above the stall surface, 8 inches (20 cm) forward from the cow side edge of the feed curb. With this rail, a 36-inch (91 cm) long neck chain can be used.

Higher tie rails improve udder cleanliness (Zurbrigg et al., 2005), but may have an adverse effect on neck lesions, lying time and lameness (Bouffard et al., 2017), so some debate exists regarding the appropriate height.

However, there is greater confidence regarding the horizontal location of the tie rail relative to the feed manger. Providing greater space behind the rail decreased the risk for neck and knee injuries, increased both the frequency and duration of lying bouts, but also slightly increased the risk for dirty udders (Bouffard et al., 2017).

Resting Space

Stall dimensions must be appropriate for standing, lying, rising and resting without causing injury, pain or fear. Stalls must meet the needs of the cow for comfort and the caregiver for cleanliness and ease of milking. Cows vary in size between and within herds. The first step in planning stall size is the measurement of first lactation and mature cows in the herd. Rump heights and hook-bone widths are useful measures to estimate several other body dimensions. Since several body dimensions are proportional, ratios provide reasonable estimates of dimensions for different classes (e.g., calves, cows) and breeds of cattle. Stalls of different sizes may be built in recognition of the variation in cattle size and the needs within a herd.

Space sharing loop dividers are preferred and the key dimensions for stall length, width and tie rail location are given in Table 4 and shown in Figure 6. The 30 inches between the rear of

the loop and the edge of the stall platform facilitates backing out of the stall and stepping over the gutter.

The feed curb defines the resting space for the cow in front of the stall, much like a brisket locator in a freestall. Feed curbs are often built to retain feed in the manger, but any curb in excess of 4 inches (10 cm) in height above the stall platform will impact the forward movement of the front leg as the cow rises – making transitioning between lying and standing difficult.

Width recommendations for tie stalls are generally greater than those for freestalls, in an attempt to accommodate the milker. In the US, over three-fourths of tie stall operations (76.4%) had stall widths of 46 inches or more (Table 5; USDA, 2010). For tie stall housed cattle that are milked in a parlor, freestall width recommendations should be followed. Wider stalls have been shown to promote longer lying times, reduce lameness and decrease the risk for neck lesions, but also carry a low risk for dirtier legs and flanks (Nash et al., 2016; Bouffard et al., 2017).

It is recommended to have a 70-inch bed for first lactation cattle, and a 72-inch bed for mature cows (Anderson, 2008a). In the US it was observed that platform lengths for stalls on tie stall operations were generally longer than on stanchion operations. (Table 6) Approximately 40% of tie stall operations had platform lengths of 70.0 inches or more (USDA, 2010).

Increasing stall platform length has been associated with decreased risk for hind claw rotation - an indication of poor claw health (Zurbrigg et al., 2005), fewer hock lesions (Busato et al., 2000; Kiel et al., 2006) and knee lesions (Bouffard et al., 2017), but an increase in the risk of dirty udders (Zurbrigg et al., 2005; Bouffard et al., 2017).

Waterer Location

Fresh, clean water is essential for the health and well-being of animals. Access to functional waterers is essential for cattle to satisfy their need for water. Water should be easily accessible at all times, and there should be sufficient waterers to accommodate the number of animals.

In a tie stall facility, waterers should be located so that there is clear space vertically above the trough for the head - so that the cow can fully immerse her muzzle in the trough. As the cow's head is typically 24 inches (61 cm) long, there should be no obstruction within the area

24 inches (61 cm) above the lip of the trough (OMAFRA). Troughs (upper edge) should be mounted 18 inches (46 cm) above the stall surface. Water flow rate to the bowls should be monitored in several bowls throughout the barn and with a minimum flow rate of 3-5 gallons per minute (Andersson, 1984).

Cow Trainer Use and Location

The electric cow-trainer consists of an electrified rod mounted horizontally a few centimeters above the cow's back and perpendicular to the spine (Figure 7). If a cow arches her back when she is standing in the front of the stall, e.g. for urinating, she will contact the cow-trainer and receive an electric shock. The animals learn to step backwards before urinating or defecating, in order to avoid shocks. This backward movement of the cow results in urine and feces going into the gutter rather than the back end of the platform, thus keeping the stalls and animals cleaner, reducing labor and simplifying management (Hultgen, 1991).

Cow trainers are banned in some European countries but continue to be used in North America. In the US, 72.6% of tie stall farms used a trainer (NAHMS 2007). In Canada, 76% of 317 Ontario dairy farms that operate a tie stall facility utilize trainers (Zurbrigg et al. 2005), with the belief that they are essential for positioning of the cow, in order to maintain stall cleanliness. However, the scientific evidence to support the use of cow trainers is weak. It has been reported that cows in stalls with trainers were 30% cleaner and had less heel horn erosion than cows in stalls without trainers (Bergsten and Pettersson (1992). In contrast, the use of cow trainers has been associated with dirtier udders and hind limbs as well as a greater risk for hock lesions (Zurbigg et al., 2005). Additionally, cow trainers have been associated with more silent heats, mastitis, ketosis and increased risk for culling at the herd level (Oltenacu et al., 1998). It has also been reported that the use of cow trainers reduced productive life by 2-3 months (Sölkner and Essl, 1990).

If herds are to continue to use trainers, they must be regularly adjusted, maintained and correctly located, so that cows are not shocked needlessly. The correct location for the trainer for mature Holstein cows is 48 inches (122 cm) forward from the rear point of the curb and located initially 2 inches (5 cm) above the backline of the cow. After a brief period of training, the trainers may be lifted to 4 inches (10 cm) above the back (OMAFRA). It has been demonstrated, however, that once cows have received an electrical shock from the trainer they quickly learn to change their posture and movement to avoid contact with the trainer and this avoidance behavior remains after the electrical current to the trainer is turned off (Hultgren, 1991). Some researchers have suggested that it may only be necessary to use the

trainers for 2 days per week, to keep cows trained, a compromise that has merits when the welfare of the cow is considered (Anderson, 2008).

If cow trainers are not used to position the cow, the use of tail ties may assist keeping tails out of dirty gutters. A tail tie allows for part of the switch to be attached to an elastic ring. The elastic ring is then tied to a line that is suspended from the ceiling. This allows the cow limited freedom to move her tail, but when properly tied, suspends the switch out of the gutter, thus reducing the risk of manure contamination, allowing for better hygiene. Currently however, there is no scientific evaluation of this approach.

Scientific Welfare Indicator Analysis

Unfortunately, the literature pool for tie stall design recommendations and injury incidence is small, with minimal data coming from North America, primarily Canada. Considerably more research has been done on stall design in free stall barns, and its impact on cow comfort and injury incidence. The majority of the US data has been pulled from previous NAHMS reports and USDA data. A visual summary of tie stall design and its impact on animal outcomes is presented in table 4.

Locomotion

Leg injuries and lameness are a common and highly visible animal well-being concerns on many commercial dairy farms across North America. Lameness, assessed using locomotion scoring or a modified scoring system developed specifically for tie stall cows (Gibbons et al., 2014; Leach et al., 2009), suggests a mean overall herd lameness prevalence of approximately 22% (Cook, 2003: 20%; Popescu et al., 2013: 19%; Popescu et al., 2014: 27%; Nash et al., 2016: 24%). This is very similar to or slightly less than studies from freestall herds.

Using a unified one to three locomotion score, the percentage of sound (non-lame) cows per operation (score of 1) was similar across tie stall, freestall and open/dry facilities in the United States (Table 7). The percentage of moderately and severely lame cattle were similar across housing types (USDA, 2014).

Hock & Knee Injuries

In the United States a greater percentage of tie stall cattle had a hock score of two or three (hair loss, abrasion or swelling) as compared to freestall and open/dry lot cattle (Table 8;

USDA, 2010). Overall, 23.5% of cows had hock lesions. However, these values were still lower than those observed in the Canadian studies.

In two Canadian studies, mean hock injury prevalence affected 58% of cows (Zurbrigg et al., 2005; Nash et al., 2016) (44 and 72% respectively), while 65% of knees (carpi) were similarly affected in one study (Nash et al., 2016). These rates of physical injury are again very similar to that seen in freestall housed dairy herds, suggesting no significant difference between the two housing systems.

Body Condition Score

Body condition score (BCS) can be used as a proxy to evaluate feed availability and animal health. A BCS of < 2.25 can be an indicator of inadequate nutrient availability, or illness. In the US, tie stall and freestall operations had a similar low percentage of animals scored < 2.25 (Table 9; USDA, 2010).

Hygiene score

Hygiene score can be used as a method to evaluate sanitation and waste management on a dairy farm. Hygiene is a critical component of producing quality milk. Multiple studies have shown a relationship between udder hygiene and somatic cell counts (Schriener and Ruegg, 2003; Reneau et al., 2005). Increased bacterial counts in milk have also been associated with poor udder hygiene (Elmoslemany et al., 2009). Hygiene is impacted by stall design and manure management. In addition to milk quality, proper sanitation of animal facilities helps minimize animal disease, minimize generation of odors and dust, minimize pest and parasites and minimize the spread of pathogens.

As part of the Dairy 2007 data collection, 39,196 animals were hygiene scored across 477 operations in the United States. This included 102 tie stall facilities, 27 stanchion bars, 282 freestalls, 30 dry lots and 36 other, multiple animal area facilities. Overall there were no differences across housing types in the percentages of cows with a hygiene score of 1 (clean; Table 10). A greater percentage of tie stall cattle had a hygiene score of 3 as compared to freestall cattle, but this was similar to those in a dry lot facility (USDA, 2010).

In the same study quoted above, the use of cow trainers and their impact on hygiene was evaluated. The use of cow trainers was associated with cleaner cows with a higher percentage of cows on operations with trainers having a hygiene score of 1 compared with cows on operations without trainers (Table 11; USDA, 2010). Almost twice the percentage of

cows had a hygiene score of 3 on operations that did not use cow trainers compared with cows on operations that did use cow trainers (23.6 and 14.1%, respectively). Trainer location was not associated with hygiene scores. The distance from the trainer to the gutter or from the trainer to the stall bed was not associated with cleanliness.

Disease Incidence

There is a lack of research comparing disease risk, udder health and mortality between tie stall and loose housing systems. The majority of the research is dated and only one peer reviewed study was from the United States (Cox et al., 1986). The USDA NAHMS does have some information available on producer identified health problems by primary housing type used for lactating cattle. The challenge with using producer identified data is that each producer may have a slightly different disease definition.

A higher percentage of cows on tiestall and freestall operations experienced clinical mastitis, infertility, or a displaced abomasum compared with cows in other housing types. Lameness affected the highest percentage of cows on freestall operations (18.4 percent) compared with cows in other housing type (Table 12; USDA, 2010).

A study utilizing Norwegian dairy herds, evaluated housing system and herd size interactions and associations with performance and disease incidence (Simensen et al., 2010; Simensen et al., 2007). A total of 620 herds were housed in freestalls and 192 in tie stalls with an average herd size of 26 cows. The overall incidence rate of disease was 51.8% for tie stalls and 53.7% for freestalls. The cull rate was 47% for tie stalls and 44% for freestalls. Herd size was associated with all of the findings of disease incidence and milk production between tie stall and freestall facilities. The authors concluded that performance and health is not universally better in small freestalls than in tie stalls.

Milk Quality and Production

Operation average rolling herd average (RHA) milk production increased as herd size increased for both tie stall/stanchion barns and parlor facilities (Table 13). Production was slightly lower overall for tie stall/stanchion barns as compared to parlor facilities (USDA 2016).

Bulk tank somatic cell count (BTSCC) can be used an indicator of overall herd milk quality. Tiestall/stanchion and freestall barns had similar percentages of cows in BTSCC breakdown,

indicating no difference overall milk quality across herds housed in either facility (USDA, 2014).

While BTSCC can provide an indication of overall milk quality, it is important to evaluate milk quality and udder health at an individual cow level. A Canadian study that encompassed 106 farms over a one-year period evaluated the incidence rate of clinical mastitis (CM) across tie stall and freestall herds. A total of 3,149 cases of CM were recorded during the study periods. There was a difference in pathogens isolated from tie stall versus freestall facilities. Tie stall facilities had a higher incidence of Staphylococcus aureus, Streptococcus uberis, coagulase-negative Staphylococcus, and environmental Streptococcus spp. Freestall facilities had a higher incidence of CM due to Escherichia coli and Klebsiella. The overall incidence rate of CM was 26.6% for tie stall facilities and 19.1% for freestall facilities (Olde Reikerink, et al., 2008). The authors noted that regional differences, bedding material differences and management styles could directly explain the significant differences in CM between the two housing systems.

A Norwegian study evaluating tie stalls and freestalls noted that milk production was 134 kg lower in freestall facilities as compared to tie stalls ($p < 0.05$), however, there was no difference in mastitis or between the two facility types (Simensen et al., 2010).

Reproductive and Metabolic

Infertility problems, defined as not pregnant > 150 days in milk, affected 14.9% of the US dairy population in 2006 (Table 12; USDA, 2010). This number was similar across tie stall and freestall facilities. The percentage of cows that experienced retained placenta was also similar between tie stall and freestall facilities. Other reproductive problems (dystocia and metritis) were slightly lower in tie stall cattle as compared to those housed in a freestall (4.7% vs 7.8%).

A field study evaluated 55 cases of uterine torsion noted that primiparous cows were found to be at lower risk of uterine torsion when they were alone in a calving pen versus a tie stall. No significant association was found between calving location of cows and uterine torsion, although cows housed in a group pen tended to at greater risk for uterine torsion compared to those housed in a tie stall barn.

A slightly greater percentage of tie stall cattle had milk fever or diarrhea for more than 48 hours as compared to cattle housed in a freestall or dry lot (Table 12). A similar percentage of cattle in tie stall and freestall barns had a displaced abomasum.

Non-Ambulatory Cows

Non-ambulatory is defined as not standing or, recumbent for > 24 hours. In 2002, non-ambulatory cattle were banned from entering the food supply. In 2014, 76.5% of US dairy operations had at least one non-ambulatory cow (USDA, 2016).

Minimal data is available to evaluate if there is a difference in non-ambulatory cows between housing systems. A study from over 30 years ago observed no difference in rate of non-ambulatory cows between tie stall and free stall facilities (Cox et al., 1986).

Mortality

In the United States, lameness or injury, mastitis and calving problems each accounted for 1% or more of cow mortality (USDA, 2010). Mastitis accounted for a slightly greater percentage of cow deaths in free stall operations as compared to tie stall and stanchion facilities (1.2 vs 0.7%, respectively). The percentage of cattle in a tie stall or freestall facility that were euthanized due to lameness or injury (1.2 and 1.3%, respectively) or calving problems (1.4 and 1.0%) were similar.

Economic Impact

This section will compare the startup cost of a new tie stall versus other facility types. Secondly, it will review costs incurred to make that transition away from a tie stall or stanchion to a free stall or bedded pack barn. Finally, this section gives estimates as to the total impact to the US dairy industry if tie stall barns and stanchion barns were to be eliminated.

Cost to the Individual Farmer

Comparisons of costs between different types of housing are difficult to make because there are many variables involved in the design, site selection, and construction. In addition to the cost of facilities, other factors play a major role in the type of facilities that are used. These factors include inherited facilities, management style, personal preference, culture and beliefs, aversion to equipment usage, and preferred herd size. Furthermore, the performance of the animals (health, reproduction, milk production, profitability) are impacted by the facilities they are housed in and the management style and preferences of the dairy farmer. Therefore, finances alone cannot dictate the type of facilities that are used.

If built and used correctly, tie stalls can be as viable a housing choice as any other system, when managed under best management practices (Morabito and Bewley, 2017). Tie stalls may be appealing to producers because of their lower investment cost, as compared to freestall housing with a parlor or robotic system. Some estimates on various types of dairy housing alternatives (freestall, bedded pack and tie stall) in Pennsylvania are presented in table 14 (McFarland, 2016).

When building a freestall barn, design considerations include: number of rows of stalls in barn (2, 3 4 or 6), feed delivery (drive through or drive by), and whether a milking system (parlor or robotics) is needed. In table 14, the four freestall, and two bedded pack designs are all more expensive than the tie stall barn, but number of cows are different too. For the loose housing (freestall and bedded pack) alternatives, the milking parlor is a significant contributor to the overall facility cost.

Excavation, electrical and plumbing, permitting, and engineering can add a significant amount to the total cost of a project. Tie stall barns may have a smaller footprint than freestall barns with parlors for the same number of cows. Tie stalls will generally be the lower cost alternative for herds of 100 cows or less (smaller footprint, lower milking equipment cost), but are the least flexible for varying herd size as there is a finite number of stalls available.

Loose housing lends itself toward larger herd size and more mechanization (manure handling, milking, etc). Additionally, loose housing allows for more flexibility when it comes to expanding the size of the herd. A very general statement would be that over 150 cows favor a parlor and under 75 cows favors a tie stall. However, not all dairy farmers want to invest in more mechanization and not all want to have large herd sizes that can only be handled with non-family/hired labor.

Determining an average cost for producers to transition away from an existing tie stall to a new freestall or bedded pack barn are difficult to estimate. Cost of transitioning can depend on many factors, these include: if a facility can be renovated, or if a new facility must be built, if a new milking system is needed, what type of milking system is needed, what is available for land space for the footprint of the barn, what type of manure management system will be utilized based on bedding management and the nutrient management plan.

Most people overestimate the value of existing buildings and under estimate the cost of renovating it for alternative uses. Therefore, it is recommended if the projected cost of

remodeling exceeds two thirds to three quarters the cost of a new facility, then a new facility should be considered (McFarland, 2016).

Forced transition away from tie stalls implies higher investment cost per cow (average of 63 cows in current tie stalls) than in new tie stalls of similar size. In addition, many of the current tie stalls will not have been fully depreciated and paid for. A forced transition away from tie stalls will likely result in a percentage of producers exiting the dairy industry as they will not be able to afford to build a new facility, or do not want to change their management to meet the needs of a freestall facility.

For the 38.9% of operations with tie stall housing (USDA, 2010), an operation employed on average 1.8 full time persons that had duties directly related to the dairy's operation. These tie stall farms also employed 1.6 part-time persons. Given the 17,987 farms with primarily tie stall housing, this translates to 32,376 full time and 11,242 part-time persons with duties directly related to the dairy's operation. Eliminating tie stalls would in turn eliminate jobs

Cost to the Industry

A transition away from tie stalls has likely much greater consequences for the number of dairy farmers and dairy farm families than for the number of dairy cows and milk production. Milk production is likely to remain unaffected because of the trend that small farms go out of business and average herd sizes of remaining farms keeps increasing.

On the other hand, many dairy farmers and their families would also be affected. It is unlikely that most dairy farmers that operate tie stalls will transition their operations to loose housing given the cost of transitioning for small herds (average 63 cows). If just half of the current tie stall operations found they could not make the transition to new loose housing or remodeling existing facilities into loose housing, it would affect close to 9,000 dairy farms with 16,000 full time employees and 5,000 part-time employees.

Societal Impact

The social cost of a transition would be high, especially in communities where tie stalls are part of the culture or belief system. According to Elizabethtown College's Young Center for Anabaptist and Pietist Studies, there are close to 9,000 plain sect households that operate dairy farms in Pennsylvania, New York and Ohio alone. Considering other Plain Sect communities as prevalent throughout the Mid-West, it is estimated that approximately 50% of all tie stall facilities are operated by a member of the plain sect community.

Ordnung (church "rules") is an indirect and underlying factor in Amish dairy farmers' concerns about the possibility of needing to move away from tie stall dairying. To the degree that the ordnung governing farming keeps farming small-scale and limits mechanization, ordnung concerns are related to plain sect farmers' resistance to moving away from tie stalls, given the significant costs and would be feasible only for larger operators. Farming within the ordnung works against expanding herd sizes and scale of operation, which they think would be necessary to finance a shift to non-tie stall operations.

An additional area that directly relates to ordung involves manure management, where non-tie stall barns require different systems of manure collection that would not be easy, practical, or cost-effective within current ordnung parameters as well as within the small scale envisioned by those ordnung parameters.

Additional limitations to plain sect communities that would impact the transition to different facility types include:

- Costs in making the change (refitting barns, perhaps needing to build entirely new facilities)
- Tie stalls allow low-tech manure collection and cleaning. Methods of manure collection and cleaning that accompany free stall arrangements were considered too expansive or suited only for large operations.
- Require large capital investment to make a transition and larger herd sizes to make it economically feasible. Question becomes whether to stay in dairy at all, not whether to borrow money to refit a barn.
- Increased dairy regulations add production cost but deliver no higher milk price.

It is important to note that the Amish of the Lancaster settlement surveyed for this data are, in general, toward the progressive end of the national Amish ordnung spectrum, with regard to technology and openness to technological change generally. They may not represent Amish sentiment nationally. Many Amish dairymen, in smaller and more conservative settlements, in Wisconsin, upstate New York, Kentucky, other parts of Pennsylvania, etc., might have direct church ordnung objections that would make freestall operations impossible to accept, rather than the more indirect, small-scale economic objections and reservations shared.

Conclusions

In conclusion, based on current research available, tie stall facilities that implement BMP provide equal opportunities for lactating dairy cattle well-being in comparison to those housed in other types of facility specifically when compared to freestall facilities. Tie stall facilities tend to have fewer severely lame cows as compared to freestall facilities. Reported disease incidence, BTSCC, mortality, BCS less than 2.25, hygiene and locomotion score of 1 are similar in tie stall and freestall systems. Tie stalls tend to have a greater percentage of cows with a hock & knee score and hygiene score of 3 as compared to freestall facilities.

More research is needed to evaluate the type of facility, age of facility, environmental control in the facility, lameness rates, disease risk, udder health, and welfare of cows that are housed in tie stalls and compare these values to those obtained in other housing systems. An evaluation of regions that have newer tie stall facilities with the comforts found in modern freestall barns (tunnel ventilation, environmental control, appropriate stall size and bedding surface) should also be performed to evaluate the differences between old and new facilities. This will help evaluate if recommendations are being implemented, and if these recommendations improve animal well-being. Furthermore, there is minimal research evaluating access to exercise and its effects on disease risk. Studies that compare access to exercise for tie stalls and freestalls that have been constructed for environmental control and cow comfort are needed.

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Figures

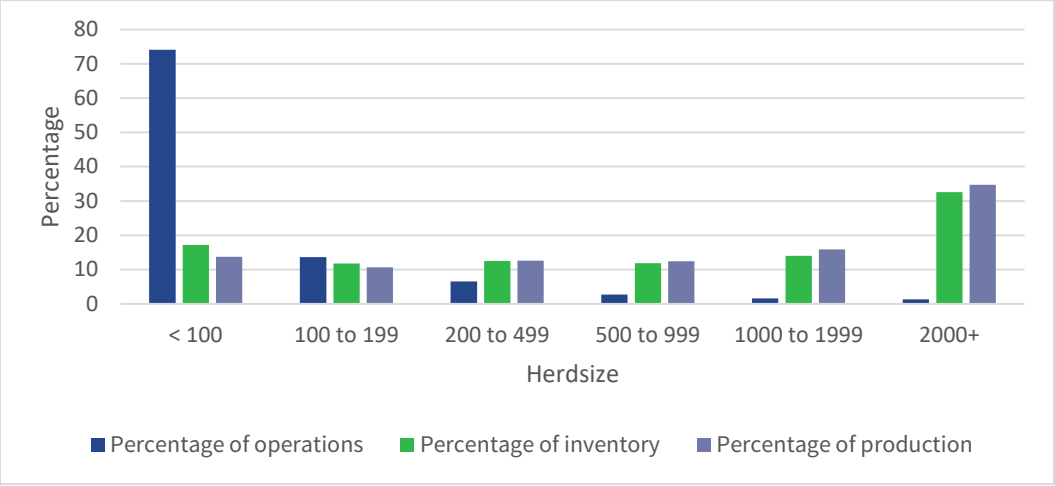

Figure 1. Percentage of operations, dairy cattle inventory and production by herd size. NASS data – reference: Farms, Land in Farms, and Livestock Operations 2012 Summary (February 2013) USDA, National Agricultural Statistics Service

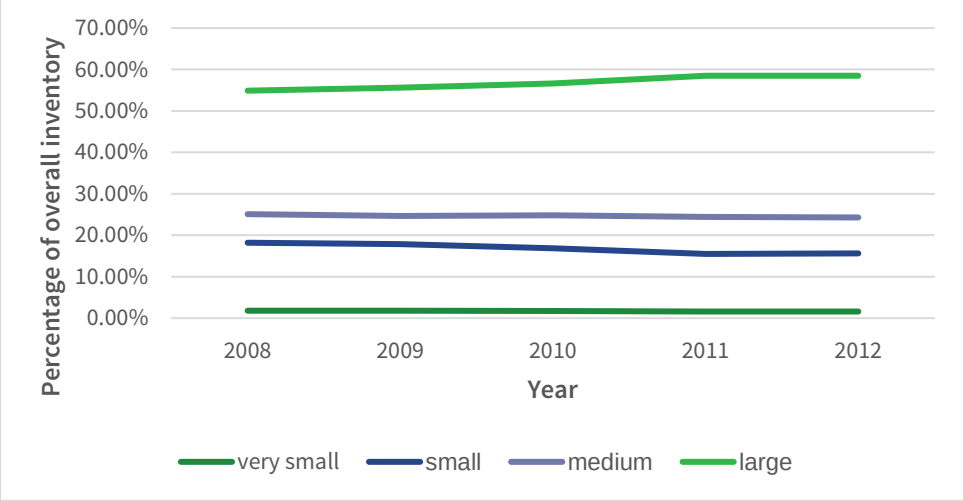

Figure 2. Percentage of US dairy herd inventory by herd size. NASS data –reference: Farms, Land in Farms, and Livestock Operations 2012 Summary (February 2013) USDA, National Agricultural Statistics Service

Figure 3. A sand conversion using a landscape timber bedding retainer. Note in some regions timber may not be allowable and can be replaced by angle-iron, fiber glass or plastic retainers.

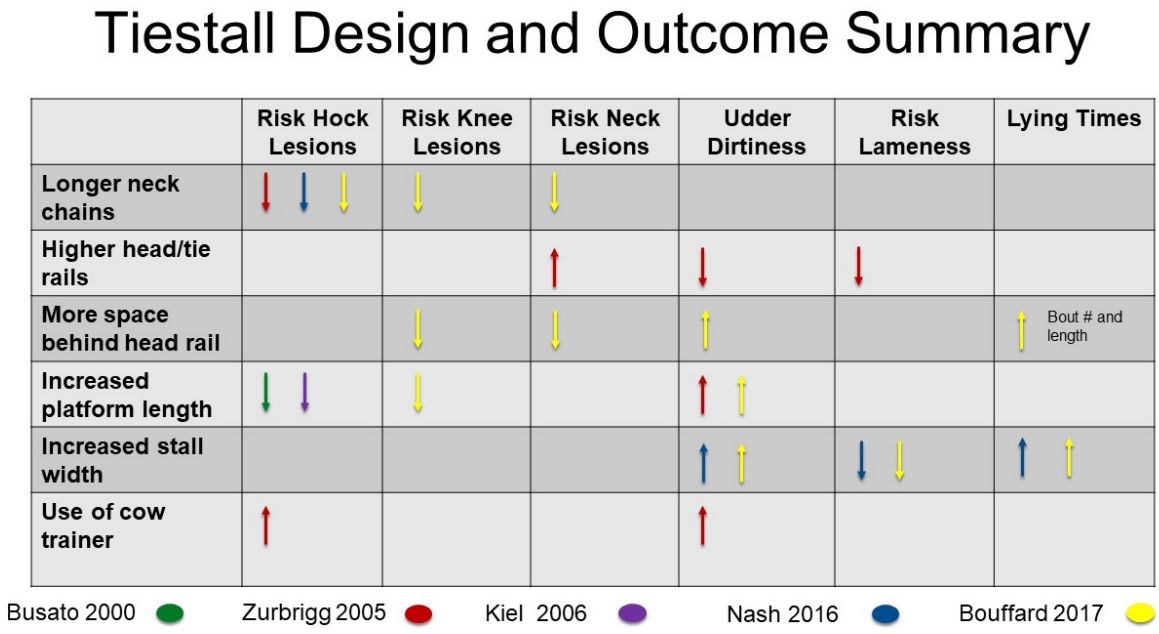

Figure 4. Summary of ties stall design and animal outcomes

Figure 5. A stanchion barn conversion with a high tie rail and longer chain to facilitate lunging. High tie rail, long chains and a low feed curb provide for greater freedom in new tie stall facilities. Note the cow has free access to the water cup, with no obstruction above.

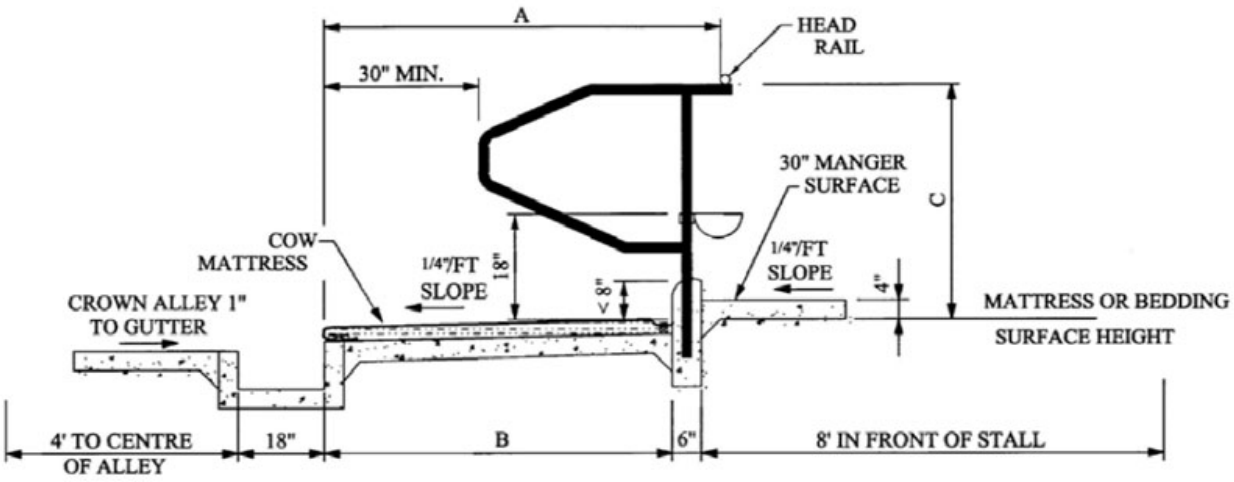

Figure 6. The diagram shows a tie stall with a head rail. The table shows variations in stall dimensions for Holstein cows - First Lactation, Milking and Dry Cows. Nonetheless, it's good advice to measure your cows before deciding on stall sizes. (Courtesy of Harold House, OMAFRA)

Figure 7. Cow trainer placement relative to the withers

Tables

Table 1. Herd_size demographics from the 2012 NASS Census of Agriculture

Number of dairy cattle	Number of operations	Percentage of operations	Percentage of inventory	Percentage of production
1 to 29	18,800	32.4	1.6	1.0
20 to 49	9,700	16.7	4.3	3.2
50 to 99	14,500	25.0	11.3	9.5
100 to 199	7,900	13.6	11.8	10.7
200-499	3,800	6.6	12.5	12.6
500 to 999	1,570	2.7	11.9	12.4
1,000 to 1,999	950	1.6	14	15.9
2,000+	780	1.3	32.6	34.7
Total	58,000	100	100	100

Table 2. Percentage of operations by primary housing type used for lactating cows, and herd size (NAHMS Dairy 2014 reference)

	Herd Size									
	Very small (< 30)		Small (30–99)		Medium (100–499)		Large (500+)		All operations	
Primary housing type	%	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Tie stall or stanchion	42.6	(6.5)	58.1	(2.4)	12.1	(1.9)	1.2	(0.7)	38.9	(1.7)
Pasture	17.6	(5.0)	5.8	(1.1)	8.0	(1.6)	1.5	(0.6)	7.5	(1.0)
Freestall[a]	18.5	(5.4)	24.3	(2.1)	68.1	(2.6)	76.4	(1.8)	39.6	(1.5)
Open/dry lot[b]	8.4	(3.7)	5.5	(1.1)	6.7	(1.3)	17.0	(1.4)	7.3	(0.8)
Other[c]	12.9	(4.3)	6.3	(1.3)	5.2	(1.3)	3.9	(1.1)	6.7	(0.9)
Total	100.0		100.0		100.0		100.0		100.0	

[a]Includes Freestall with no access to open/dry lot and Freestall with access to open/dry lot
[b]Includes Open/dry lot/multiple animal outside area without barn or shed (with or without shade structures) and Open/dry lot with open shed/loafing shed
[c] Includes Multiple animal inside area/barn and Not housed on this operation

Table 3. Percentage of operations by primary housing type used for lactating cows, and by region (NAHMS Dairy 2014 reference)

	Region			
	West		East	
Primary housing type	**Percent**	**Std. error**	**Percent**	**Std. error**
Tie stall or stanchion	3.2	(2.4)	42.2	(1.8)
Pasture	15.3	(3.6)	6.8	(1.0)
Freestall[a]	48.6	(3.5)	38.3	(1.6)
Open/dry lot[b]	30.0	(3.1)	5.2	(0.9)
Other[c]	2.8	(1.4)	7.0	(1.0)
Total	100.0		100.0	

[a]Includes *Freestall with no access to open/dry lot* and *Freestall with access to open/dry lot*
[b]Includes *Open/dry lot/multiple animal outside area without barn or shed (with or without shade structures)* and *Open/dry lot with open shed/loafing shed*
[c] Includes *Multiple animal inside area/barn* and *Not housed on this operation*

Table 4. Key dimensions for tie stall design (see Figure 6 for key to measures)

Cow Size	Estimated Weight (lbs.)	Dimension (in)				
		A	B	C	Width	Chain + Clasp Total Length
Small	1400	84	70	46	54	34
Medium	1600	86	72	48	57	36
Large	1800	90	76	50	60	38

Table 5. Percentage of operations by operation average stall width, and by housing type (NAHMS Dairy 2007 reference)

	Housing Type							
	Tie stall		Stanchion		Freestall		All Operations	
Average Stall Width (Inches)	**Pct.**	**Std. Error**	**Pct.**	**Std. Error**	**Pct.**	**Std. Error**	**Pct.**	**Std. Error**
< 42.0	1.6	(0.9)	33.4	(10.0)	4.9	(1.7)	7.8	(2.0)
42.0 to 43.9	5.5	(2.3)	12.0	(7.0)	22.8	(3.6)	13.5	(2.1)
44.0 to 45.9	16.5	(4.0)	7.5	(4.4)	40.2	(4.1)	24.7	(2.6)
46.0 to 47.9	31.0	(5.5)	21.4	(7.6)	26.6	(4.0)	27.7	(3.1)
48.0 to 49.9	30.1	(5.3)	23.0	(9.9)	4.9	(2.6)	18.8	(2.9)
50.0+	15.3	(4.4)	2.7	(2.7)	0.6	(0.5)	7.5	(2.1)
Total	100.		100.		100.		100.	

Table 6. Percentage of operations by average platform length, and housing type (NAHMS Dairy 2007 reference)

	Housing Type					
	Tie stall		Stanchion		All Operations	
Average Platform Length (Inches)	**Percent**	**Std. Error**	**Percent**	**Std. Error**	**Percent**	**Std. Error**
< than 60.0	1.4	(0.8)	20.0	(7.8)	6.1	(2.2)
60.0 to 64.9	13.4	(4.1)	60.3	(9.4)	25.3	(4.5)
65.0 to 69.9	43.7	(5.9)	19.7	(7.1)	37.6	(4.9)
70.0 to 74.9	34.5	(5.3)	0.0	(--)	25.8	(4.1)
75.0 or more	7.0	(3.2)	0.0	(--)	5.2	(2.4)
Total	100.0		100.0		100.0	

Table 7. Operation average percent cows by locomotion score, and by primary housing type used for lactating cows (NAHMS 2014 reference)

	Primary Housing Type							
	Tie stall or stanchion		Freestall[a]		Open/dry lot[b]		All operations[c]	
Locomotion score	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
1	89.6	(2.1)	89.7	(1.0)	91.7	(2.2)	90.2	(0.9)
2	8.6	(2.0)	7.1	(0.6)	6.3	(1.3)	7.3	(0.7)
3	1.8	(0.4)	3.2	(0.5)	2.0	(1.0)	2.6	(0.3)
Total	100.0		100.0		100.0		100.0	

[a] *Includes Freestall with no access to open/dry lot and Freestall with access to open/dry lot*
[b] *Includes Open/dry lot/multiple animal outside area without barn or shed (with or without shade structures) and Open/dry lot with open shed/loafing shed*
[c] The All Operations category includes categories not presented in this table (those with Pasture and Other housing for lactating cows)

Table 8. Operation average percent cows by hock lesion score, and by primary housing type used for lactating cows (NAHMS Dairy 2014 reference)

	Primary Housing Type							
	Tie stall or stanchion		Freestall[a]		Open/dry lot[b]		All operations[c]	
Hock lesion score	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
1	69.8	(5.2)	88.8	(2.4)	96.1	(0.8)	82.5	(2.4)
2	23.1	(3.9)	9.1	(2.0)	3.8	(0.7)	13.9	(1.9)
3	7.2	(1.7)	2.1	(0.5)	0.1	(0.1)	3.6	(0.7)
Total	100.0		100.0		100.0		100.0	

[a] *Includes Freestall with no access to open/dry lot and Freestall with access to open/dry lot*

[b] *Includes Open/dry lot/multiple animal outside area without barn or shed (with or without shade structures) and Open/dry lot with open shed/loafing shed*

[c] The All Operations category includes categories not presented in this table (those with Pasture and Other housing for lactating cows)

Table 9. Operation average within herd prevalence of thin cows (BCS less than 2.25), by primary housing type used for lactating cows and by herd size and by region (NAHMS Dairy 2014 reference)

	Herd Size (number of cows)						Region					
	Small (30–99)		Medium (100–499)		Large (500 or more)		West		East		All operations	
Primary housing type	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Tie stall or stanchion	6.5	(2.6)	1.3	(0.9)	3.0	(0.0)	6.5	(2.6)	1.3	(0.9)	6.3	(2.4)
Freestall	7.6	(5.7)	2.9	(0.8)	2.7	(0.5)	3.1	(0.6	3.8	(1.3)	3.8	(1.2)
Open/dry lot	28.7	(11.4)	0.5	(0.4)	0.2	(0.1)	0.6	(0.4)	21.7	(11.6)	9.1	(6.7)

Table 10. Percent cows by hygiene score and by primary housing type for lactating cows (NAHMS Dairy 2007 reference)

	Housing Type							
	Tie stall or stanchion		Freestall		Dry lot		All Operations	
Hygiene Score	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error
1	46.1	(2.7)	47.9	(2.3)	43.7	(6.1)	46.6	(1.7)
2	36.6	(1.7)	42.1	(1.9)	34.0	(3.3)	39.5	(1.3)
3	17.3	(1.4)	10.0	(1.1)	22.3	(4.5)	13.9	(0.9)
Total	100.0		100.0		100.0		100.0	

Table 11. Percentage of cows by hygiene score, and by use of cow trainers (NAHMS Dairy 2007 reference)

	Cow Trainers			
	Yes		No	
Hygiene Score	Percent	Std. Error	Percent	Std. Error
1	50.3	(3.1)	37.6	(5.0)
2	35.6	(1.9)	38.8	(3.6)
3	14.1	(1.5)	23.6	(2.8)
Total	100.0		100.0	