Minimizing Stress to Enhance Cow Health and Productivity

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Take Home Messages

- Management, housing, and handling of animals should consider cows' behaviour, their physical environment, and their social environment to reduce physiological, psychological, and social stress and enhance their health, welfare, and productivity.
- Little things add up (or potentially even multiply!). Even small stressors and moderate/subclinical diseases can negatively impact cow behaviour and production.
- Don't forget to take care of yourself! So many farmers put their animals first and it is crucial to take care of your own physical and mental health as it will benefit everyone around you, including your animals. Also, remember there are other factors that contribute to your well-being besides just health.

Introduction

Managing the stress of dairy cattle has vast implications for animal health and productivity. While the combination of good management, housing, and handling can enhance animal health and optimize production and efficiency, shortcomings in any of those aspects can cause stress. Temple Grandin uses this definition of stress: it is "a condition in an animal that results from the action of one or more stressors that may be of either external or internal origin; whether a stressor can be considered as harmful depends on the way an organism is able to cope with a threatening situation" (Temple Grandin citing van Borell, 2001). Stressors can have both physiological and psychological effects on animals, which can lead to changes in cow behaviour and health status, negatively impacting cow welfare, production, and reproduction (Figure 1).

Various aspects of management, housing, and handling can cause stress related to cows' physical environment and comfort, as well as their social environment. Management considerations to reduce animal stress include animal grouping and regrouping, feeding, and dry off management. Animal housing impacts health and productivity includes comfort of lying spaces, stocking densities, and heat stress abatement. Handling methods that work with cows' natural behaviour can reduce stress, labour, and injuries to animals and handlers. A lot of research has demonstrated the negative consequences of different stressors in isolation, but in commercial farms, there may be interacting effects between multiple stressors. Therefore, multiple stressors may add up or they may even interact in a synergistic but negative way.

Health disorders can also cause stress and behavioural changes that have negative effects on cow productivity. Even cows with moderate lameness and subclinical ketosis exhibit changes in behaviour and production (King et al., 2017, 2018). In the 2016 National Dairy Study, which surveyed Canadian dairy stakeholders (where 68% of respondents were farmers), animal welfare was identified as the top-ranking management priority and lameness was the top disease priority (Bauman et al., 2016). But despite cow health and welfare being a priority for the industry, the true prevalence of disease is often underestimated if we focus our efforts on severe cases, even though subclinical cases are much more prevalent. Although farmers are aware of these issues and consider lameness and mastitis to be painful, farmers and even their veterinarians often underestimate the number of lame cows. Thus, these disorders remain prevalent on Canadian dairy farms, negatively impacting cow health, welfare, and productivity.

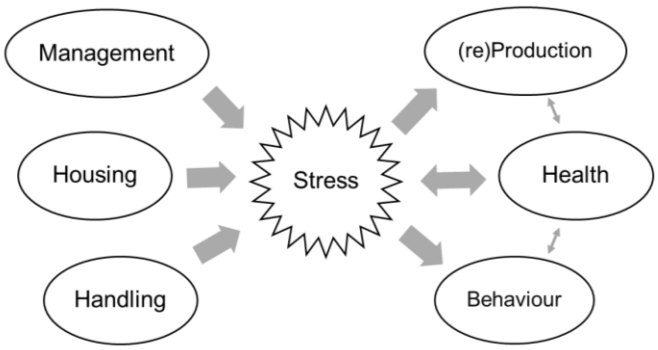

Figure 1. Flowchart to visualize the interconnections between some key factors associated with stress in dairy cattle.

Finally, with so much attention placed on animal welfare, the perspective of farmers is often overlooked, even though they are the ones providing care to animals daily, having the greatest impact on animal welfare (Kauppinen et al. 2010). There is growing evidence that the health and welfare of dairy cows are related to the well-being of dairy farmers (Hansen and Østerås, 2019; King et al., 2021). This connection aligns with the 'One Welfare' approach, related to 'One Health'. The One Welfare framework "describes the interrelationships between animal welfare, human well-being, and the physical and social environment" (Pinillos, 2018). Therefore, when considering ways to reduce stress for dairy animals, it is crucial to remember that the best way to improve animal welfare may be to also focus on improving the well-being of the farmer.

▪ Management and Stress

Grouping & Regrouping

Group composition can be optimized and maintained to minimize the psycho-social stress experienced by dairy animals. For pregnant first-half heifers and first lactation cows, being housed with older cows can impact their behaviour, resulting in lower lying times (Kaufman et al., 2016), eating times, dry matter intake (DMI), and milk yield (Bach et al., 2006) and they need more ketosis treatments after calving (Østergaard et al., 2010). Housing first-lactation cows with older animals can also interact with high stocking densities, as shown by greater fecal cortisol concentrations, indicating that first-lactation cows may have difficulties adapting to competition (Huzzey et al., 2012).

Regrouping cows with other cows or into a new group can also be a stressful event; it takes up to 24 to 72 hours for cows to re-establish their social hierarchy (Moran and Doyle, 2015). This is especially stressful on cows in their first lactation just after calving. Regrouping events negatively affect behaviours such as lying, ruminating, and feeding. Regrouping events can further increase agonistic behaviour between cows and impact milk production (von Keyserlingk et al., 2008; Schirmann et al., 2011). Because regrouping cows frequently before calving may constantly introduce new competitive interactions, cows should not be regrouped more than once per week. Other recommendations to reduce regrouping stress include limiting stocking density in those pens, introducing new animals in pairs instead of alone (especially when grouping heifers with older cows), or even better, creating stable 'all-in-all-out' pens when possible.

Feed Management

How, when, and what cows consume has huge implications for cow health and productivity. Improper feed management can cause physiological stress and can be compounded by social stress. In terms of the physiological impacts of feed management, there are effects not only on ruminal health, but also on udder health, hoof health, and productivity.

Changes in diet can impair rumen function by disrupting gut microbiota and decreasing feed intake. This is especially stressful during the transition period and at dry off, where cows are already undergoing considerable physiological and psychological stress. Ruminal stability is best supported by small, frequent meals consumed slowly, with minimal feed sorting. Increasing the number of meals a cow eats in a day can also improve her fat-correct milk yield. Further, increasing the frequency of fresh feed delivery and feed pushups can improve access to feed, reduce feed sorting, and decrease the displacement of subordinate cows from the bunk, increasing milk yield at a herd level.

Udder health may be improved by encouraging cows to eat after milking to allow teat canals to close before cows lie down.

Finally, hoof health can be impacted by access to feed. Herds with barriers creating separate feeding spaces had a lower lameness prevalence compared with those with a post-and-rail (Sarjokari et al., 2013). Lameness was also less prevalent in herds with wider feed alleys (Sarjokari et al., 2013; Westin et al., 2016) and more feed bunk space (Matson et al. 2022). Therefore, continual access to feed throughout the day with limited competition is essential for healthy feeding behaviour.

Dry Off Management

Late-lactation cows can experience a significant amount of physiological stress when dried off abruptly, as indicated by high intramammary pressure and cortisol concentrations in the blood and feces (Bertulat et al., 2013). This is especially important for high-producing cows (producing > 20 kg/d) and may not be necessary for lower-producing cows (producing < 15 kg/d). Skipping milkings or reducing milking frequency reduces milk yield before dry off and milk leakage after dry off, but this does not always translate to a reduced risk of intramammary infection (IMI) after dry off (Gott et al., 2016).

Although study results have varied, there is a general consensus that the target milk yield at dry off should be 15 kg/d or less to improve udder health. First-lactation cows exhibiting milk leakage and those dried off abruptly had a higher risk of IMI, whereas multiparous cows were more likely to have IMI with gradual milking cessation (Gott et al., 2016). Furthermore, primiparous cows' lying time is often more sensitive than that of multiparous cows relative to their milk yield at dry off or in response to abrupt dry off. Therefore, there may be differences in optimal dry-off strategies for cows based on parity.

▪ Housing and Stress

Rest Areas

In all barn types, cows need to rest on clean and dry bedding, maintained at an adequate depth; otherwise, cows will stand excessively or perch in their stalls, leading to the development of hoof lesions and lameness. The increased time spent standing in slurry can increase the risk of developing soft tissue lesions, and inadequate rest time can reduce blood supply to the hooves and the ability to heal. Unfortunately, subordinate cows also spend less time lying down and more time standing and perching, which increases their risk of soft tissue lesions and lameness (Galindo and Broom, 2000). It is also beneficial to separate sick and lame cows and provide them with more comfortable bedding (e.g., bedding pack) and easy access to the milking area.

Type of bedding: Sand bedding has become the well-known 'gold standard' choice of bedding to support udder and hoof health. Relative to non-sand surfaces and mattresses, sand bedding has been associated with 10%-point reductions in lameness prevalence (so 20% of a herd instead of 30%) and greater milk production (reviewed by Bicalho and Oikonomou, 2013). Lame cows are also better able to perform natural lying behaviour in deep-bedded sand stalls.

Quantity of bedding: Cows prefer and will spend more time lying down on deep-bedded stalls (either sand or sawdust) compared with mattresses. Each extra kilo of bedding per stall can increase cows' lying time significantly (Tucker et al., 2009). At the bare minimum, bedding should be at least 2.0–2.5 cm deep to

reduce lameness and knee injuries; increasing bedding depth above 7.6 cm further reduce levels of lameness, dirty udders, dirty flanks, and hock injuries.

Quality of bedding: The management of bedding is just as important in achieving a comfortable rest area for cows. In Canadian tie stall herds, wet bedding was associated with higher odds of lameness (Jewell et al. 2019).

Stall size: In freestall herds, obstructed lunge space and not fitting the width of lying stalls was associated with lameness (Westin et al., 2016). Higher curbs at the back of stalls have also been associated with greater lameness prevalence (King et al., 2016; Matson et al., 2022).

Stocking Density

Overcrowding cows can lead to limited access to rest areas, feeding space, water, and other valued resources. This can create stress both physiologically and psychologically because cows must compete for limited resources. Aggression and competitive displacements can impair healthy feeding behaviour and result in higher fecal cortisol levels, indicating higher activity or stress (Proudfoot et al., 2018). Overstocking cows can also impair immune function and increase the risk of subclinical ketosis in fresh cows. Higher stocking densities have also been related to greater lameness prevalence and lower milk yield in both robotic and conventional freestall herds, whether it is the number of cows relative to lying stalls (King et al. 2016; Westin et al. 2016) or feed bunk space (Matson et al. 2022). In herds with robotic milking systems, the number of cows per robot negatively affects milking frequency, showing the importance of all aspects of stocking density (King et al., 2016).

Heat Stress

Heat stress is an obvious physiological stressor for dairy cows, as it can cause immune suppression and may contribute to systemic inflammation. Whether exposure to heat stress is during lactation, the dry period, or gestation, heat stress impairs the health, fertility, feed intake, and milk production of cows and the immunity and growth rates of calves. Furthermore, the daughters and even granddaughters of pregnant cows exposed to heat stress show lower milk production and a lower probability of survival (Laporta et al., 2020).

▪ Handling Methods and Stress

Low-stress handling methods are a simple way to promote the health and well-being of dairy cattle. Safer handling methods for animals are also safer for farmers, as 45% of livestock-related injuries are related to handling cattle (Canadian Agriculture Industry Reporting). Studies of dairy cow handling methods generally show negative effects of aversive handling on cow behaviour, but not necessarily on milk yield (Munksgaard et al. 2001; Rushen et al., 2001).

Most studies examining the effects of handling methods on animal productivity and welfare have been focused on the beef industry. Beef farms participating in animal handling training, whether occasionally or regularly, have been shown to use better handling techniques and, therefore, their cattle performed fewer undesirable behaviours during handling compared with that of non-trained farms (Ceballos et al., 2018a). On non-trained farms, there was also a decline in handling quality over the course of the day. Ceballos et al. (2018b) also observed that poor handling was related to high reactivity of heifers, as well as more undesirable behaviours and accidents. While they did not directly link negative handling or reactivity to pregnancy rates, poorly handled heifers had dirtier perineal regions, which was associated with lower pregnancy rates.

Here are some key do's and don'ts adapted from Temple Grandin (Grandin, 1989; Grandin et al. 1998):

- Don't make sudden movements, and avoid exposing cows to sudden noises, moving air and objects, and flashes of light.
- Do remain calm and alternate between 'driving pressure' and 'drawing pressure' when moving cows. This relates to their flight zone, also called the pressure zone, zone of awareness, or zone of influence. Cattle can be easily sorted through a gate by using a combination of 'driving pressure' when the flight zone is entered and 'drawing pressure' when the handler is just outside the boundary of the flight zone.
- Don't isolate cows. If necessary, minimize the amount of time and ensure that the cow has visual contact with others.
- Don't overcrowd cows in small pens, such as holding pens.
- Do make first experiences positive, because cows remember previous negative experiences. Cows can be trained and exposed to new situations slowly, habituating them to that experience. But if the exposure is negative, they can be conditioned to experience fear. Livestock previously handled gently will be less stressed and easier to handle in the future, which will lead to fewer injuries, better performance, and weight gain.
- Be consistent, or at least consistently inconsistent. Although animal learning is specific, animals can generalize to similar situations and can adapt to new things, but novelty and inconsistent handling generally cause stress. That being said, animals raised in variable environments are less likely to be stressed when confronted with novelty, and so it is important to slowly introduce novelty to younger animals. Calves and heifers have great potential to learn if given the chance.

Cow Health, Productivity, and Behaviour

As mentioned before, we know that animal welfare and lameness are top-ranking priorities for dairy farmers and other stakeholders. Despite that, the true prevalence of disease is often underestimated because farmers and veterinarians often focus primarily on severe cases, yet subclinical cases are much more prevalent. Regarding lameness, severe cases (mean of 2 to 4% of cows/herd) are a major focus across Canada but are less prevalent than moderate lameness (21 to 26% of cows/herd; King et al. 2016; Jewell et al. 2019), where cows still limp and likely experience pain or discomfort. Similarly, ketosis is a common disorder clinically affecting 2 to 12% cows/herd and subclinically affecting 21 to 41% of cows (Tatone et al., 2017). Subclinical ketosis is especially common after calving when energy demands are high, and cows are unable to consume enough feed to meet those demands. Subclinical mastitis contributes to 48% of mastitis costs for Canadian dairy farmers, while only 34% is due to clinical mastitis (Aghamohammadi et al., 2018).

Regardless of the health disorder, there are generally negative consequences of disease in terms of production, behaviour, and the overall health and welfare of dairy cattle. Furthermore, severe and clinical cases of disease cause obvious and outward signs of sickness, whereas subclinical diseases present without symptoms. However, even cows with moderate lameness and subclinical ketosis exhibit changes in behaviour and production (King et al. 2017a, 2018), which may be subtle but are also significant (1.6 to 2 kg/d).

Fortunately, with modern precision technologies, we can monitor cow behaviour and detect symptoms that appear to be subclinical to the naked eye. General trends for cow activity, rumination time, and milk yield are consistent between studies, whether comparing sick and healthy animals or looking within affected cows relative to diagnosis day. Despite a large variation between cows, there are also certain variables (particularly rumination time) that consistently deviate at least one day before other variables (milk yield) and may act as early indicators of disease. There are also differences across diseases such that acute health disorders (i.e., displaced abomasum and mastitis) are associated with deviations from those cows' baseline automated milking system data, whereas more chronic disorders (i.e., subclinical ketosis and lameness) are associated with significant, but subtle, longer-term changes in milk production and behaviour.

Numerous other researchers have documented reductions in milk yield and rumination time beginning from one up to ten days before diagnosis of several disorders, such as milk fever, ketosis, mastitis, metritis, pneumonia, hock and hoof lesions, and digestive disorders (reviewed by King and DeVries, 2018). Depending on the disorder, milk conductivity may increase, whereas activity may decrease (when measured as steps per day; Edwards and Tozer, 2004). However, activity as measured by rumination collars only records the upward motion of the head, and therefore, this may not be a useful way to assess health status. Some researchers reported reductions in rumination time and activity occurring one to five days before diagnosis of metabolic disorders, pneumonia, and metritis, but others found no difference in rumination time or activity between lame and non-lame cows (reviewed by King and DeVries, 2018).

▪ Human Health and Cow Health

When people think about human and animal health, they often focus on physical health. However, we must also consider our mental and emotional health. Farmer mental health is a key component of agriculture and an emerging area of concern, as was demonstrated in the 2019 Report of the Canadian House of Commons Standing Committee on Agriculture and Agri-Food, “Mental Health: A Priority For Our Farmers”.

Canadian farmers experience higher levels of stress, anxiety, and depression than the average citizen (Jones-Bitton et al., 2019). This trend along with higher rates of suicide are unfortunately seen around the world because farming is one of the most physically dangerous and mentally stressful occupations (Milner et al., 2013). There is also evidence that livestock producers may experience greater rates of stress-related symptoms and suicide than crop producers (Kanamori and Kondo, 2020), making the need for mental health support even more important.

Health is just one of the many factors that contributes to the well-being of human and non-human animals. For humans, there are eight dimensions to our overall well-being: physical, mental/emotional, spiritual, social, occupational, financial, intellectual, and environmental. As you can see, there are many aspects of well-being to think about.

There are also connections between human and animal well-being. According to pig and dairy farmers in Norway, taking care of their own well-being ranked as the most important way to improve animal welfare, but it was the most difficult action to put into practice (Kaupinnen et al., 2010). Hansen and Østerås (2019) found that dairy farmers who felt stressed, lonely, or weary, scored lower on their animal welfare indicator (an overall scores looking at production, culling, and cow health); alternatively, herds scored higher on their animal welfare indicator when the farmer reported better occupational well-being (including work satisfaction, income, optimism about the future and control, and feeling appreciated as a farmer).

In our study of robotic milking herds, we found that those who worked mostly alone on the farm had greater anxiety and depression levels than those who worked with others (King et al., 2021). Farmers who also used automated feeders had lower stress, anxiety, and depression scores, compared with those feeding conventionally. It is also possible that dairy farmers using robotic milking systems may be experiencing less stress, anxiety, and depression than the average Canadian farmer (compared to all commodity groups surveyed by Jones-Bitton et al., 2019). However, there may also be negative consequences of using automation and the associated alerts and alarms, which may be new sources of stress in addition to the financial stress of new investments and learning to use new systems. Tse et al. (2018) found that switching to robotic milking systems improved producers’ time flexibility, ability to manage cow health and employees, and their quality of life and that of their cows. In our study, cow lameness prevalence was related to farmer stress and anxiety scores (King et al., 2021), supporting the notion that human and animal health are connected.

Future research in this area will help producers to think and talk more about their mental health and that it can improve our understanding and ability to manage farm stress, enhancing the well-being of farmers and animals, their productivity, efficiency, and profitability. Openly discussing these challenges and our shared values of animal welfare and sustainability enhances public trust and compassion towards farmers. Most importantly, to ensure the success and sustainability of animal agriculture, we must support the health and well-being of both farmers and cattle.

Conclusions

This proceedings chapter emphasizes the relationships between management, housing, handling, and cow stress. Stress can be physiological or psycho-social; therefore, we must consider cows' physical and social environments and their behaviour. Stress can affect cow behaviour, health, and re(production). Inversely, poor health, even it is if only a moderate or subclinical health disorder, can act as a stressor and negatively impact cow behaviour and production. Finally, farmers should remember to take care of their own physical and mental health, as it will also have positive benefits for their families and animals.

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References

Aghamohammadi, M., et al. 2018. Herd-level mastitis-associated costs on Canadian Dairy Farms. Front. Vet. Sci. https://doi.org/10.3389/fvets.2018.00100

Bach, A., C. Iglesias, M. Devant, and N. Ràfols. 2006. Performance and feeding behavior of primiparous cows loose housed alone or together with multiparous cows. J. Dairy Sci. 89:337.342.

Bauman, C.A., H.W. Barkema, J. Dubuc, G.P. Keefe and D.R. Kalton. 2016. Identifying management and disease priorities of Canadian dairy industry stakeholders. https://doi.org/10.3168/jds.2016-11057

Bertulat S., C. Fischer-Tenhagen, V. Suthar, E. Möstl, N. Isaka, and W. Heuwieser. 2013. Measurement of fecal glucocorticoid metabolites and evaluation of udder characteristics to estimate stress after sudden dry-off in dairy cows with different milk yields. J. Dairy Sci. 96:3774-3787.

Bicalho, R.C. and G. Oikonomou. 2013. Control and prevention of lameness associated with claw lesions in dairy cows. Livestock Sci. 156:96-105. https://doi.org/10.1016/j.livsci.2013.06.007

Canadian Agricultural Injury Reporting - Agriculture Related Fatalities in Canada. Retrieved from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex8274

Ceballos, M.C., A.C. Sant'Anna, et al. 2018a. Investigating the relationship between human-animal interactions, reactivity, stress response and reproductive performance in Nellore heifers. Livestock Sci. 217:65-75 https://doi.org/10.1016/j.livsci.2018.08.001

Ceballos, M.C., A.C. Sant'Anna, et al. 2018b. Impact of good practices of handling training on beef cattle welfare and stockpeople attitudes and behaviors. Livestock Sci. 216:24-31.

Edwards, J. L., and P. R. Tozer. 2004. Using Activity and Milk Yield as Predictors of Fresh Cow Disorders. J. Dairy Sci. 87:524–531. doi:10.3168/jds.S0022-0302(04)73192-6.

Gott, P.N., P.J. Rajala-Schultz, G.M. Schuenemann, K.L. Proudfoot, and J.S. Hogan. 2016. Intramammary infections and milk leakage following gradual or abrupt cessation of milking. J. Dairy Sci. 99:4005-4017.

Grandin, T. 1989. Behavioral Principles of Livestock Handling. The Professional Animal Scientist 5:1-11 https://doi.org/10.15232/S1080-7446(15)32304-4

Grandin, T., J.E. Oldfield, and L.J. Boyd. 1998. Review: Reducing Handling Stress Improves Both Productivity and Welfare. The Professional Animal Scientist 14:1-10.

Hansen, B.G and O. Østerås. 2019. Farmer welfare and animal welfare- Exploring the relationship between farmer's occupational well-being and stress, farm expansion and animal welfare. Prev Vet Med 170:104741

Huzzey, J.M., D.V. Nydam, R.J. Grant, and T.R. Overton. 2012. The effects of overstocking Holstein dairy cattle during the dry period on cortisol secretion and energy metabolism. J. Dairy Sci. 95:4421-4433. doi:10.3168/jds.2011-5037.

Jewell, M.T., M. Cameron, J. Spears et al. 2019. Prevalence of lameness and associated risk factors on dairy farms in the Maritime Provinces of Canada. https://doi.org/10.3168/jds.2018-15349

Jones-Bitton, A., C. Best, J. MacTavish, S. Fleming and S. Hoy. 2019. Stress, anxiety, depression, and resilience in Canadian farmers. Soc Psych and Psych Epi 55:229-236.

Kanamori, M. and N. Kondo. 2020. Suicide and types of agriculture: A time-series analysis in Japan. https://doi.org/10.1111/sltb.12559

Kaufman, E.I., S.J. LeBlanc, B.W. McBride, T.F. Duffield, and T.J. DeVries. 2016. Short communication: Association of lying behavior and subclinical ketosis in transition dairy cows. J. Dairy Sci. 99:7473–7480. doi:10.3168/jds.2016-11185.

Kauppinen, T., A. Vainio, A. Valros, H. Rita, and K.M. Vesala. 2010. Improving animal welfare: qualitative and quantitative methodology in the study of farmers' attitudes. Animal Welfare. 19:523-536.

King, M.T.M., S.J. LeBlanc, E.A. Pajor, and T.J. Devries. 2016. Associations of herd-level housing, management, and lameness prevalence with productivity and cow behavior in herds with automated milking systems. J. Dairy Sci. 99:9069-9079.

King, M.T.M., S.J. LeBlanc, E.A. Pajor, and T.J. Devries. 2017. Cow-level associations of lameness, behavior, and milk yield of cows milked in automated systems. J. Dairy Sci. 100:4818–4828.

King, M.T.M., S.J. LeBlanc, E.A. Pajor, T.C. Wright, and T.J. DeVries. 2018. Behavior and productivity of cows milked in automated systems before diagnosis of health disorders in early lactation. J. Dairy Sci. 101:4343-4356.

King, M.T.M., F.D. Matson, and T.J. DeVries. 2021 Connecting farmer mental health with cow health and welfare on dairy farms using robotic milking systems. Animal Welfare 30:25-38.

Laporta, J., F.C. Ferreira, V. Ouellet, B. Dado-Senn, A.K. Almeida, A. de Vries, and G.E. Dahl. 2020. Late-gestation heat stress impairs daughter and granddaughter lifetime performance. J. Dairy Sci. 103:7555-7568. doi:10.3168/jds.2020-18154.

Matson, R.D, M.T.M. King, T.F. Duffield, et al. 2022. Identifying factors associated with lameness and its impact on productivity in automated milking herds. J. Dairy Sci. 105:793-806.

Milner A, M.J. Spittal, J. Pirkis, and A.D. LaMontagne. 2013. Suicide by occupation: Systematic review and meta-analysis. British J. Psychiatry. 203:409-416.

Munksgaard, L., A.M. DePassillé, J. Rushen, M.S. Herskin, and A.M. Kristensen. 2001. Dairy cows' fear of people: social learning, milk yield and behaviour at milking. Applied Animal Behaviour Sci. 73:15-26

Østergaard, S., P.T. Thomsen, and E. Burow. 2010. Separate housing for one month after calving improves production and health in primiparous cows but not in multiparous cows. J. Dairy Sci. 93:3533.3541. doi:10.3168/jds.2009-2865.

Pinillos, R.G. 2018. The path to developing a One Welfare framework. In One Welfare: a framework to improve animal welfare and human well-being. CAB International: Oxford, UK. https://doi.org/10.1079/9781786393845.0000

Proudfoot, K.L., D.M. Weary, S.J. LeBlanc, L.K. Mamedova, and M.A.G. von Keyserlingk. 2018. Exposure to an unpredictable and competitive social environment affects behavior and health of transition dairy cows. J. Dairy Sci. 101:9309–9320. doi:10.3168/jds.2017-14115.

Rushen, J., L. Munksgaard, P.G. Marnet and A.M. DePassillé. 2001. Human contact and the effects of acute stress on cows at milking Applied Animal Behaviour Science 73:1-14.

Sarjokari, K., K.O. Kaustell, T. Hurme, et al. 2013. Prevalence and risk factors for lameness in insulated free stall barns in Finland. Livestock Sci. 156:44-52 https://doi.org/10.1016/j.livsci.2013.06.010

Schirmann, K., N. Chapinal, D.M. Weary, W. Heuwieser, and M.A.G. von Keyserlingk. 2011. Short-term effects of regrouping on behavior of prepartum dairy cows. J. Dairy Sci. 94:2312-2319.

Tatone, E.H., T.F. Duffield, S.J. LeBlanc, et al. 2017. Investigating the within-herd prevalence and risk factors for ketosis in dairy cattle in Ontario as diagnosed by the test-day concentration of ß-hydroxybutyrate in milk. J. Dairy Sci. 100:1308-1318. https://doi.org/10.3168/jds.2016-11453

Tse, C., H.W. Barkema, T.J. DeVries, J. Rushen, E. Vasseur, and E.A. Pajor. 2018. Producer experience with transitioning to automatic milking: Cow training, challenges, and effect on quality of life. J. Dairy Sci. 101:9599–9607.

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

von Keyserlingk, M.A.G., D. Olineck, and D.M. Weary. 2008. Acute behavioral effects of regrouping dairy cows. J. Dairy Sci. 91:1011-1016. https://doi.org/10.3168/jds.2007-0532.

Westin, R., A. Vaughan, A.M. de Passillé, et al. 2016. Cow- and farm-level risk factors for lameness on dairy farms with automated milking systems. J. Dairy Sci. 99:3732–3743.