Condition of surplus dairy calves at livestock dealers in Ohio: A cross-sectional study

Thesis

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By

Hannah Maggard, B.S.

Graduate Program in Animal Sciences

The Ohio State University

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Thesis Committee

Dr. Jessica A. Pempek, Advisor

Dr. Kelly George

Dr. Gregory Habing

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Abstract

Surplus dairy calves are sold soon after birth, often through a live auction or livestock dealer (e.g., a facility where large groups of calves are aggregated) before entering veal or dairy beef production chains in the United States. Our previous work demonstrated veal calves arrive to calf-raising facilities with failed transfer of passive immunity **(FTPI)** and signs of disease, but little is known regarding calf condition on arrival at livestock dealers. The objectives of this cross-sectional study were to 1) estimate the prevalence of FTPI and poor health outcomes in surplus calves at livestock dealers and 2) determine risk factors for poor health, including sale body weight, sex, and source. Two livestock dealers in Ohio were visited 2 to 3 times per week from May to September 2021, with approximately 28 calves enrolled in the study per visit for a total of 1,119 calves. One blood sample per calf was obtained to evaluate FTPI by measuring serum total protein levels (using a cutoff < 5.1 g/dL). Calves were clinically evaluated for signs of navel inflammation, depression, dehydration, fever, diarrhea, respiratory disease, and arthritis; health outcomes were dichotomized using clinically relevant cut-points. Descriptive statistics were used to describe the prevalence of calves with poor condition. A multivariable logistic regression model was used to determine if sale body weight ($<$ 40.8 kg vs $\geq$ 40.8 kg), sex (male vs female), and source (direct from dairy vs. non-direct purchasing from a live auction or livestock dealer) were risk factors for poor health outcomes. Nineteen percent (206/1091) of calves had FTPI, and those purchased directly from the dairy farm were more likely to have FTPI compared to those purchased from live auctions or livestock dealers (OR: 2.25; 95% CI: 1.25 to 4.03; $P = 0.007$). Upon clinical examination, 69.2% (769/1112) of calves were considered dehydrated, 26.3% (293/1112) had navel inflammation, and 7.33% (82/1118) were depressed. Male calves were more likely than female calves to have navel inflammation (OR: 1.86; 95% CI: 1.24 to 2.77; $P = 0.03$) and ocular discharge (OR: 1.95; 95% CI: 0.92 to 4.12; $P = 0.08$). This research highlights the opportunity for continued improvements in colostrum management for female and male surplus dairy calves, and interventions are necessary to reduce the high observed prevalence of dehydration and navel inflammation.

Dedication

Dedicated to my wonderful family and friends for their unconditional love and support and for always encouraging me to achieve my dreams. They are forever in my heart, my mind, and my determination to succeed. Additionally, to my advisor, Dr. Jessica Pempek for supporting me and always going above and beyond to display her dedication to my career; I will forever be grateful and appreciative of her. Lastly, in loving memory of my amazing grandmother, Susan Maggard, who helped me become the person that I am today.

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Vita

2017..West Jefferson High School, West Jefferson, Ohio

2021..B.S. Animal Sciences, The Ohio State University

2021 to Present...Graduate Associate, Department of Animal Sciences, The Ohio State University

Fields of Study

Major Field: Animal Sciences

Animal Welfare Science

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Chapter 1. Introduction

1.1 Defining animal welfare

Animal welfare is a complex science, yet individuals sometimes use the term 'animal welfare' relatively loosely in context or substitute it with other terms, such as 'well-being'. In addition, individuals have strong opinions about how animals should (or should not) be raised, which has led to a variety of proposed definitions for animal welfare. One definition that is commonly used and well accepted by animal welfare scientists is "the state of the individual in relation to its environment" (Broom, 1991). A second definition from the World Organization for Animal Health **(WOAH)** further defines animal welfare as "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (WOAH, 2022). Animal welfare varies on a continuum from very poor to very good and should be considered from birth on through to a humane death for individual animals (Broom, 1991). It is important to understand that animal welfare refers to the experience of the individual animal, not something assigned or given to the animal by human caretakers. Further, animal welfare considers the ability of an animal to cope (or fail to cope) with its environment (Broom, 1991).

One element of animal welfare often considered is stress. Animals can experience three types of stress: behavioral (e.g., novel situations, fear of humans); physical (e.g., injury, fatigue); or physiological (e.g., hunger, thirst) (Etim et al., 2013). The factors that can cause stress are referred to as stressors. When an animal elicits a behavioral or physiological response to cope with one or more stressors, these responses help the animal avoid physiological malfunctioning or, in other words, maintain homeostatic balance (Broom, 1991). Identifying and minimizing situations that may cause an animal distress allows for greater animal welfare, as well as growth and reproductive efficiency (Etim et al., 2013). Further, if an individual animal can control one or more aspects of its environment, this can facilitate coping and the animal's ability to maintain fitness and avoid suffering (Webster, 2001). Suffering refers to the mental state of the animal, and occurs when unpleasant, subjective feelings, such as pain, fear, frustration, deprivation, and, in some species, boredom, negatively affect the animal (Dawkins, 1990, Duncan, 2005).

In recent decades, animal welfare has been the subject of public discussion and, at times, controversy, due to ethical concerns of the quality-of-life animals might experience under human care (Fraser et al., 1997). In the 1960's, Ruth Harrison, a British animal activist, published the book *Animal Machines*, after receiving a pamphlet on Britain's "factory farming systems" and how food animals were reared (Harrison, 1964). In sum, this book described the unnaturalness of intensive housing for food animal species after the Industrial Revolution and detailed the challenges modern housing conditions posed for animal welfare. In response to the public outcry that was generated from this book, in 1965, the British government established a technical committee to review the welfare of food animals. This committee was formerly referred to as the Brambell Committee, after Professor Roger Brambell. The Brambell Committee defined the minimum standards for animal welfare, which became well known around the world as the Five Freedoms. Later, this framework was adapted to include the Five Provisions (FAWC, 2012) and aligned Animal Welfare Aims (Mellor, 2016; Table 1.1) as a more advanced alternative to the Five Freedoms.

The original Five Freedoms had great influence across many countries, yet some scientific and practical complications became apparent (Broom, 2011; Webster, 2001). For example, the Brambell Committee did not use a specific definition of animal welfare, instead, they followed an idea put forth by Barry Hughes (1982), which referred to an animal being in harmony in nature. The scientific assessment of an animal being in a single state of harmony was later questioned by some scientists (Broom, 2011). Additionally, some of the Five Freedoms conflict with one another. For example, vaccination helps prevent animal diseases, yet fear and distress might occur from handling during vaccine administration. Or, if animals have freedom to express normal behavior, they can suffer fear and distress during normal social interactions. It was not until the early 1990s that scientists agreed that animal welfare was measurable and a scientific concept (Broom, 2011).

1.2 Animal welfare assessment

Comparable to the difficulties of defining animal welfare, assessing animal welfare has also proven challenging for scientists over recent decades. Although there still remains some disagreement on which component is the most important for animal welfare, there is consensus that key determinants are: (1) the extent to which the animal can display innate behavior and live in ways that are natural to its species; (2) the animal's subjective emotional experiences; and (3) the animal's physical health and biological functioning (Fraser, 1997). To scientifically assess these three components of animal welfare, behavioral and physiological measures, as well as measures of disease are used (Barnett & Hemsworth, 1990).

Fraser et al. (1997) suggested that "animals should be able to lead reasonably natural lives" while in the care of humans. Natural conditions have influenced animals' needs and the evolutionary coping mechanisms for the species (Broom, 2011). When an animal is attempting to cope with its environment, if that environment reflects conditions that are natural for that animal, some experiences may be greater tolerated (Lund, 2006). Further, an animal's feelings are linked to both preference and motivation and associated with obtaining desired resources (Kirkden and Pajor, 2006).

Behavioral tests that measure animal preferences and choice behavior, as well as the strength of their preferences are commonly used tools in the study of animal welfare (Fraser and Matthews, 1997). Preference tests are used by ethologists to gain insight into the environmental conditions that animals may prefer by allowing the animals to choose between various resources (e.g., space, toys, bedding materials, flooring surfaces, etc.). Preference is then measured through choice behavior or quantifying the amount of time the animal spends with the resource(s) (Broom, 1988). For example, Worth et al. (2015) investigated dairy calves' preference for various bedding substrates, including sawdust, rubber, stones, and sand at 1 week of age. During the first 3 days of the study, calves were permitted access to all four substrates, restricted to each substrate for 48 hours, and then given access to all 4 substrates simultaneously for 48 hours. During the final 24 hours, lying behavior and pen location were quantified and recorded, respectively, and during the final 12 hours, play behavior was quantified. Calves showed a preference for the sawdust bedding substrate, as they spent more time lying on the sawdust compared to rubber, stones, and sand (Worth et al., 2015).

Although preference testing is a useful tool to identify if an animal prefers one environment or resource over others provided, this testing does not assess the strength of an animal's preference (Fraser and Matthews, 1997). Motivation testing allows scientists to determine whether a particular environment or resource is rewarding, with the assumption that an animal will learn to perform an operant or other task to gain access to it. For example, Keyserlingk et al. (2017) compared lactating dairy cows' motivation to access pasture compared to fresh feed following milking. The cows were trained in Phase 1 to open a weighted (7 kg) gate placed between two adjacent pens, one with feed and one without. The authors added 7 kg of weight daily until cows no longer performed the task for two consecutive days. Phase 2 of the trial was identical to Phase 1, except the weighted push-gate was positioned between the indoor pen and pasture. The cows worked at least as hard to access pasture as they did to access fresh feed 2 h after milking, indicating cows are highly motivated to access pasture.

Another element of animal welfare often quantified is abnormal behaviors, such as vocalization frequency (in some species), escape attempts, or changes in social interaction or feeding behavior, can also be used to identify negative affective states and possible animal welfare concerns (Costa et al., 2016). For example, De Paula Vieira et al. (2010) investigated the effects of individual versus pair housing in dairy calves before and after weaning from milk. Individually housed calves vocalized 3 times more than pair-housed calves after weaning. This study also found that pair-housed calves consumed more concentrate after weaning than calves housed individually. The reduced responses of the pair-housed calves to weaning may be because of social buffering, which occurs when the presence of another animal attenuates another's response during a stressful event (e.g., weaning) (Sanchez et al., 2015).

Common physiological measures used to assess animal welfare include stress hormone levels (e.g., fecal, plasma, or salivary cortisol levels), adrenal cortex activity (i.e., through glucocorticoid production and enzyme activity), and pain indicators (e.g., endorphins, ACTH, proteins) (Broom and Johnson, 1993). For example, previous studies have reported that depriving animals of important behaviors, such as lying in cattle, increases basal cortisol levels (Fisher et al., 2002). Additionally, physiological measures are used to assess pain in animals. Sylvester et al. (1998) observed an increase in cortisol concentrations in calves up to 6 hours after dehorning by four different methods (scoop, guillotine sheers, saw, embryotomy wire). The authors reported a similar cortisol in calves across the four methods, indicating that the distress experienced by calves was similar regardless of the method used.

Heart rate, respiratory rate, blood pressure, or body temperature are also commonly used indicators of biological functioning (Broom and Johnson, 1993). Increases in heart rate, or tachycardia, normally occur when an animal's level of physical activity increases. Likewise, respiratory rate and body temperature also increase during a bout of physical activity. However, these physiological indicators can also increase or decrease in the absence of physical activity through an animal's emotional response to a situation (Broom and Johnson, 1993). For example, heart rate and heart rate variability have been used to measure stress associated with aversive handling, pain associated with surgical procedures, or milking (reviewed by Kovács et al., 2012). For young calves, increased heart rate after ear-tagging (Stewart et al., 2013) and prolonged heart rate elevation (up to 3 h) without local anesthesia following disbudding with a hot iron has been reported (Stewart et al., 2008). Emotions can also alter an animal's body temperature because they are responses to internal or external events of a particular significance to the animal (reviewed by Travain and Valsecchi, 2021). For example, Stewart et al. (2008) reported a rapid decrease in eye temperature immediately following disbudding without an anesthetic. In contrast, the authors only observed a small non-significant decrease in eye temperature following disbudding with a local anesthetic.

Lastly, health refers to the "state of the animal as regards its attempt to cope with pathology" (Broom, 2011). With disease challenge, as well as with other challenges the animal might experience, poor welfare can result from either difficult or inadequate adaptation (Broom, 2011). Navel inflammation (Roccaro et al., 2022), diarrhea, and respiratory disease are the most common disease challenges affecting young calves (reviewed by McGuirk, 2008). Measures of disease frequency, such as incidence, prevalence, and mortality rates, can be used to characterize the occurrence of health events (Pfeiffer, 2010). Navel inflammation in calves is considered painful (Studds et al., 2018), and the prevalence of navel inflammation has been reported to be 26 to 27% in young veal calves on arrival at calf-raising facilities in North America (Pempek et al., 2017; Renaud et al., 2018). Diarrhea is one of the main causes of mortality in young calves (Becker et al., 2020). Calves with diarrhea experience pain (Studds et al., 2018), as well as dehydration and decreased appetite (Trefz et al., 2017). Further, Webster et al. (1985) examined the effect of different calf-raising practices on cleanliness, disease incidence, and injury across multiple farms. The proportion of farms that treated calves for respiratory disease was five to six times greater for calves purchased from an external source compared to calves reared on the dairy farm of birth. Coping with pathology is necessary for good health and biological functioning, and thus, is an important component of animal welfare. However, one measure alone is not enough to holistically assess animal welfare, and a multidimensional approach should always be considered.

Table 1.1. The original Five Freedoms of animal welfare, the updated Five Provisions, and the aligned Animal Welfare Aims[1]

Freedoms	Provisions	Animal Welfare Aims
Freedom from thirst and hunger and malnutrition	By ready access to fresh water and a diet to maintain full health and vigor	Minimize thirst and hunger and enable eating to be a pleasurable experience
Freedom from discomfort	By providing a suitable environment including shelter and a comfortable resting area	Minimize discomfort and exposure and promote thermal, physical, and other comforts
Freedom from pain, injury, or disease	By prevention or rapid diagnosis and treatment	Minimize breathlessness, nausea, pain, and other aversive experiences and promote the pleasures of robustness, vigor, strength, and well-coordinated physical activity
Freedom from fear and distress	By ensuring conditions which avoid mental suffering	Minimize threats and unpleasant restrictions on behavior and promote engagement in rewarding activities
Freedom to express normal behavior	By providing sufficient space, proper facilities, and company of the animal's own kind	Promote various forms of comfort, pleasure, interest, confidence, and a sense of control

[1]Reviewed by Mellor, D. J. (2016). Moving beyond the “Five Freedoms” by updating the “Five Provisions” and introducing aligned “Animal Welfare Aims”. Animals 6(10):59.

1.3 References

Barnett, J. L., and P. H. Hemsworth. 1990. The validity of physiological and behavioural measures of animal welfare. Appl. Anim. Behav. Sci. 25(1):177-187. https://doi.org/10.1016/0168-1591(90)90079-S.

Becker, J., G. Schüpbach-Regula, A. Steiner, V. Perreten, D. Wüthrich, A. Hausherr, and M. Meylan. 2020. Effects of the novel concept 'outdoor veal calf' on antimicrobial use, mortality and weight gain in Switzerland. Prev. Vet. Med. 176:104907. https://doi.org/10.1016/j.prevetmed.2020.104907.

Broom, D. M. 1991a. Animal welfare: concepts and measurement. J. Anim. Sci. 69(10):4167-4175. https://doi.org/10.2527/1991.69104167x.

Broom, D. M. 1991b. Assessing welfare and suffering. Behavioural Processes 25(2-3):117-123. https://doi.org/10.1016/0376-6357(91)90014-Q.

Broom, D. M. 2011. A history of animal welfare science. Acta Biotheoretica 59(2):121-137. https://doi.org/10.1007/s10441-011-9123-3.

Broom, D. M. (1988). The scientific assessment of animal welfare. Appl. Anim. Behav. Sci. 20(1):5-19. https://doi.org/10.1016/0168-1591(88)90122-0.

Broom, D. M., and K. G. Johnson. 1993. Stress and animal welfare. Chapman and Hall, London, UK. https://doi.org/10.1007/978-3-030-32153-6.

Costa, J. H. C., M. A. G. von Keyserlingk, and D. M. Weary. 2016. Invited review: Effects of group housing of dairy calves on behavior, cognition, performance, and health. J. Dairy Sci. 99(4):2453-2467. https://doi.org/10.3168/jds.2015-10144.

Dawkins, M. 1977. Do hens suffer in battery cages? Environmental preferences and welfare. Anim. Behav. 25:1034-1046. https://doi.org/10.1016/0003-3472(77)90054-9.

Dawkins, M. S. 1990. From an animal's point of view: Motivation, fitness, and animal welfare. BBS 13(1):1-9. https://doi.org/10.1017/S0140525X00077104.

De Paula Vieira, A., M. A. G. von Keyserlingk, and D. M. Weary. 2010. Effects of pair versus single housing on performance and behavior of dairy calves before and after weaning from milk. J. Dairy Sci. 93(7):3079-3085. https://doi.org/10.3168/jds.2009-2516.

Duncan, I. 2005. Science-based assessment of animal welfare: Farm animals. Rev. Sci. Tech. Off. Int. Epiz. 24:483-492.

Etim, N. N., M. E. Williams, E. I. Evans, and E. E. A. Offiong. 2013. Physiological and behavioral responses of farm animals to stress: implications to animal productivity. Am J Adv Agric Res. 1(2):53-61. https://doi.org/10.1017/S1751731117003755.

FAWC (Farm Animal Welfare Council). 2009. Five Freedoms; Farm Animal Welfare Council, the National Archives, 2012. Accessed Oct. 22, 2022. http://webarchive.nationalarchives.gov.uk/20121007104210/http:/www.fawc.org.uk/freedoms.htm.

Fraser, D., and Matthews, L.R. 1997. Preference and motivation testing. Pages 159-173 in Animal Welfare. M. C. Appleby and B. O. Hughes, ed. CAB International, New York, NY.

Fraser, D., D. Weary, E. Pajor, and B. Milligan. 1997. A scientific conception of animal welfare that reflects ethical concerns. Pages 187-205 in Animal Welfare. M. C. Appleby and B. O. Hughes, ed. CAB International, New York, NY.

Harrison, R. 1964. Animal Machines. CAB International, London, UK.

Hughes B. O. 1982. The historical and ethical background of animal welfare. Pages 1-9 in How well do our animals fare? Proc. 15th annual conference of the reading University Agricultural Club.

Kirkden, R. D., and E. A. Pajor. 2006. Using preference, motivation and aversion tests to ask scientific questions about animals' feelings. Appl. Anim. Behav. Sci. 100:29-47. https://doi.org/10.1016/j.applanim.2006.04.009.

Kovács, L., V. Jurkovich, M. Bakony, O. Szenci, P. Póti, and J. Tőzsér. 2014. Welfare implication of measuring heart rate and heart rate variability in dairy cattle: Literature review and conclusions for future research. Animal 8(2):316-330. https://doi.org/10.1017/S1751731113002140.

Lund, V. 2006. Natural living—A precondition for animal welfare in organic farming. Livest. Sci. 100(2):71-83. https://doi.org/10.1016/j.livprodsci.2005.08.005.

Mellor, D. J., and L. Murray. 1989. Effects of tail docking and castration on behaviour and plasma cortisol concentrations in young lambs. Research in Veterinary Science 46(3):387-391. https://doi.org/10.1016/S0034-5288(18)31185-8.

Mellor, D. J. 2016. Moving beyond the "Five Freedoms" by Updating the "Five Provisions" and Introducing Aligned "Animal Welfare Aims". Animals 6(10). https://doi.org/10.3390/ani6100059.

Pfeiffer, D. 2010. Quantifying disease occurrence. Pages 19-28 in Veterinary Epidemiology: An Introduction. John Wiley and Sons, Oxford, UK.

Roccaro, M., M. Bolcato, N. T. Masebo, A. Gentile, and A. Peli. 2022. Navel healing and calf fitness for transport. Animals 12(3):358. https://doi.org/10.3390/ani12030358.

Sanchez M. M., K. M. McCormack, and B. R. Howell. 2015. Social buffering of stress responses in nonhuman primates: Maternal regulation of the development of emotional regulatory brain circuits. Soc Neurosci. 10(5):512-526. https://doi.org/10.1080/17470919.2015.1087426.

Stewart, M., H. M. Shepherd, J. R. Webster, J. R. Waas, L. M. McLeay, and K. E. Schütz. 2013. Effect of previous handling experiences on responses of dairy calves to routine husbandry procedures. Animal 7: 828–833. https://doi.org/10.1017/S175173111200225X.

Stewart, M., K. J. Stafford, S. K. Dowling, A. L. Schaefer, and J. R. Webster. 2008. Eye temperature and heart rate variability of calves disbudded with or without local anesthetic. Physiol. Behav.93:789–797. https://doi.org/10.1016/j.physbeh.2007.11.044.

Sylvester, S., K. Stafford, D. Mellor, R. Bruce, and R. Ward. 1998. Acute cortisol responses of calves to four methods of dehorning by amputation. Aust. Vet. J. 76(2):123-126. https://doi.org/10.1111/j.1751-0813.1998.tb14544.x.

Travain, T., and P. Valsecchi. 2021. Infrared thermography in the study of animals' emotional responses: A critical review. Animals 11(9):2510. https://doi.org.10.3390/ani11092510.

Trefz, F. M., I. Lorenz, A. Lorch, and P.D. Constable. 2017. Clinical signs, profound acidemia, hypoglycemia, and hypernatremia are predictive of mortality in 1,400 critically ill neonatal calves with diarrhea. PLoS One 12:e0182938. https://doi.org/10.1371/journal.pone.018293828817693.

Tucker, C. B., D. M. Weary, M. A. G. von Keyserlingk, and K. A. Beauchemin. 2009. Cow comfort in tie-stalls: Increased depth of shavings or straw bedding increases lying time. J. Dairy Sci. 92(6):2684-2690. https://doi.org/10.3168/jds.2008-1926.

von Keyserlingk, M. A. G., A. Amorim Cestari, B. Franks, J. A. Fregonesi, and D. M. Weary. 2017. Dairy cows value access to pasture as highly as fresh feed. Sci. Rep. 7(1):1-4. https://doi.org/10.1038/srep44953.

Webster, A. J. F. 2001. Farm animal welfare: The Five Freedoms and the free market. Vet. J. 161(3):229-237. https://doi.org/10.1053/tvjl.2000.0563.

Webster, A. J. F., C. Saville, B. M. Church, A. Gnanasakthy, and R. Moss. 1985. Some effects of different rearing systems on health, cleanliness and injury in calves. Brit. Vet. J. 141:472-483. https://doi.org/10.1016/0007-1935(85)90042-9.

Wilson, D. J., A. Justice-Allen, G. Goodell, T. J. Baldwin, R. T. Skirpstunas, and K. B. Cavender. 2011. Risk of Mycoplasma bovis transmission from contaminated sand bedding to naive dairy calves. J. Dairy Sci. 94(3):1318-1324. https://doi.org/10.3168/jds.2010-3692.

WOAH (World Organization for Animal Health). 2022. Animal welfare. Accessed Oct. 19, 2022. https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-welfare/.

Worth, G. M., K. E. Schütz, M. Stewart, V. M. Cave, M. Foster, and M. A. Sutherland. 2015. Dairy calves' preference for rearing substrate. Appl. Anim. Behav. Sci. 168:1-9. https://doi.org/10.1016/j.applanim.2015.04.003.

Chapter 2. Surplus dairy calf welfare

2.1 Overview of the surplus dairy calf industry

There are approximately 9.3 million dairy cows in the United States (USDA, 2020). Dairy cows generally give birth to one calf every year, resulting in roughly 9.3 calves born annually. When calves are born on a dairy farm, heifer (i.e., female) calves are typically retained on the dairy farm as replacements for the milking herd. Bull calves (i.e., male calves) or any heifers that are not needed as replacements are sold soon after birth. The calf population that is sold from the dairy farm is commonly referenced in the literature as “surplus” because these animals exceed the requirements of the dairy operation (Bolton et al., 2021, Creutzinger et al., 2021). Historically, surplus calves have predominantly been male. However, because more strategic breeding practices are being utilized in dairy production, such as the use of sexed semen and the growing demand for crossbreeding with beef breeds, a larger proportion of female calves are being sold as surplus, as well (Bolton et al., 2021).

The specific fate of these surplus calves varies across the world, but most calves enter red meat production (Bolton and von Keyserlingk, 2021). Regardless of region, however, the demand for surplus calves is low, resulting in low sales prices and, because of this, it is sometimes a more economically viable decision for producers to euthanize surplus calves on farm, as opposed to selling them (Bolton and von Keyserlingk, 2021). In the United States, surplus calves are typically sold through live auctions, individual livestock dealers at buying stations (i.e., facilities where large groups of calves are aggregated), or both before entering “bob” veal, “special-fed” veal, or dairy beef production. Surplus calves marketed as bob veal are 150 pounds or less than 3 weeks of age (VQA, 2018). Calves marketed as special-fed veal are approximately 500 pounds or 23 weeks of age at harvest (VQA, 2018). Lastly, surplus dairy calves can also enter dairy beef production, where they are marketed at 1,300 to 1,500 pounds or 12 to 14 months of age (reviewed by Creutzinger et al., 2021). Approximately 597,197 surplus calves were harvested for veal in the United States in 2019, with nearly two-thirds (61.8%) harvested for bob veal and one-third (33.5%) harvested for formula-fed veal (USDA-FSIS, 2020). Dairy beef calves are typically reported by the USDA-FSIS (2020) as ‘steers’, which also includes purebred beef breeds. Although this makes it difficult to report precise estimates for this calf sector, we suspect the majority of surplus calves in the United States are harvested as dairy beef.

Notwithstanding the calf’s destination, they can be exposed to a variety of stressors in the first weeks of life that impact their welfare. Examples of these stressors include suboptimal newborn care on the dairy farm of birth prior to sale (Wilson et al., 2021); long-distance transport (Grandin, 2020; reviewed by Roadknight et al., 2021a); irregular feeding schedules during marketing; and co-mingling with other animals (Marcato et al., 2018).

2.2 Suboptimal newborn calf care

Historically, compared to female dairy calves, very limited research has been dedicated to predominantly male surplus dairy calves. Suboptimal neonatal calf care on the dairy farm of birth is an animal welfare concern, as this can increase the calf's risk of morbidity, mortality, and antimicrobial use (Wilson et al., 2021). A large survey-based study conducted by the USDA National Animal Health Monitoring System **(NAHMS)** in 2014 reported nearly all (97.6%) dairy producers sold their male dairy calves prior to weaning, and 2.4% of male calves died on the farm of birth prior to sale (Shivley et al., 2019). There is some evidence that calf care on the dairy farm of birth differs between male and female calves that remain on the dairy farm as replacements for the milking herd, with males receiving suboptimal care. Therefore, it is important to explore these differences in care and their impact on calf welfare in more detail.

2.2.1 Colostrum management

Management of the newborn dairy calf is essential for its survival and productivity for the remainder of its life. One crucial aspect of newborn dairy calf care is colostrum management. Calves are born agammaglobulinemic, which means that immunoglobulins are not successfully transferred to the calf *in utero* because the placenta of the cow separates the maternal and fetal blood supply (Godden, 2008). Therefore, calves are entirely dependent on the absorption of maternal immunoglobulins from colostrum (Godden, 2008), and successful transfer of passive immunity **(TPI)** through colostrum is essential for the prevention of disease and early mortality (Atkinson et al., 2017; Renaud et al., 2017). Negative outcomes associated with failed transfer of passive immunity **(FTPI)** have been well documented and include increased pre-weaning morbidity and mortality, increased duration and contagiousness of disease, reduced productivity (e.g., growth rates), reduced milk production in the first lactation (for females), and increased culling rates (Atkinson et al., 2017). For successful TPI to occur, the method, quality, quantity, and timing of the first colostrum feeding is critical to ensure serum IgG concentrations ≥ 10 mg/mL or successful TPI (Atkinson et al., 2017; Godden, 2008).

One factor that can influence successful TPI is the method of colostrum delivery. Hand feeding colostrum with a nipple bottle is often considered best practice (as opposed to suckling colostrum from the dam or open bucket feeding) as it allows dairy producers to monitor the quality, quantity, and timing of colostrum feedings to reduce calves risk of FTPI (Shivley et al., 2019). Hänninen et al. (2007) reported that sucking colostrum from a nipple bucket (compared with drinking from an open bucket) improved calf rest and sleep. However, according to the most recent USDA NAHMS (2014) study, 3.7% of male calves did not receive colostrum, and 1.5% of the male dairy calves received colostrum by suckling the dam as the sole means of providing colostrum, compared to 0% of heifer calves that obtained colostrum through suckling (Shivley et al., 2019). By utilizing different colostrum delivery methods based on calf sex, the risk of FTPI might be increased for male compared to female calves.

When considering the quantity of colostrum that should be provided to calves, it is recommended that calves are fed at least 10-12% of their total body weight during the first colostrum feeding, regardless of sex (Godden, 2008). Since male dairy calves often have higher birth weights compared to female calves, the quantity of colostrum should be adjusted depending on each animal individually; yet, it is not common practice to adjust colostrum quantity based on calf body weight, and there is some evidence that bull calves are sometimes fed lower volumes of colostrum compared to female calves (Godden, 2008; Shivley et al., 2019). For example, Shively et al. (2019) reported bull calves received 4.8 L of colostrum in the first 24 hours of life, compared to 5.5 L for heifer calves. To explore these neonatal calf care discrepancies, Wilson et al. (2021) reported that some producers shared the sentiment that, *"Feeding a bull calf is just more extra work."*

Calves are also at risk of FTPI if the first colostrum feeding is delayed, as the gut decreases in permeability when colostrum is not immediately fed to newborn calves. For example, Fisher et al. (2018) randomized calves to receive the first colostrum feeding at different times and found higher absorption efficiency and serum IgG levels when calves were fed colostrum at 45 min vs 6 and 12 h postpartum. After 6 hours postpartum, there is a progressive decline in calves' ability to absorb immunoglobulins (Fisher et al., 2018). Therefore, recommendations suggest providing the first colostrum feeding to calves as soon as possible postpartum (i.e., within 1-2 hours) and before 6 hours postpartum (Godden, 2008). A survey-based study that focused on management of pre-weaned bull calves on dairy operations in the United States reported a 1.2 h delay for the first colostrum feeding for bull relative to heifer calves (Shivley et al., 2019). Wilson et al. (2021) described attitudinal differences among dairy producers related to the timeless of colostrum provision for male vs female calves, whereby on producer in a focus group expounded, *"I'm always like, 'Oh my gosh, I have to get colostrum into it!' Like it bothers me,"* and this producer later explained, *"And sometimes, honestly, it doesn't work. Then, I just have to put it [out of] my head. If it's a bull calf I feel a bit better."*

Since the timing of the first colostrum feeding is critical for the calf's health in the short and longer-term, timeliness should always be monitored closely to allow for adequate absorption of immunoglobulins and TPI, independent of calf sex.

If inadequacies exist between the quality, quantity, and timing of colostrum feedings, calves' risk of FTPI increases. For example, Wilson et al. (2000) found that 43% of veal calves arriving at calf-raising facilities had FTPI due to insufficient colostrum. Additionally, Renaud et al. (2020) documented 24% of male calves at auction facilities in Ontario, Canada had FTPI (defined as STP < 5.2 g/dL). Pempek et al. (2017) also determined that 22.5% of veal calves arriving at growers in Ohio had FPTI using a cutoff of 6.0 g/dL. This high prevalence of FTPI With high rates of mortality and morbidity increasing with FTPI in calves, the risk for increased preweaning morbidity and mortality, increased duration of illness, increased contagiousness when infected, reduced growth, reduced milk production in the first lactation for females, and culling rates increases, allowing for multiple health and welfare concerns to occur (Atkinson et al., 2017).

2.2.2 Navel care

The umbilical cord is an important placentally derived structure, important for maintaining an adequate blood supply between the fetus and placenta through pregnancy (Fordyce et al., 2018). During the last stage of the birthing process, the umbilical cord ruptures, leaving the umbilical stump and cord remnant exposed on the calf's abdomen (Fordyce et al., 2018). Strategic naval antisepsis is a key feature of newborn calf care management and if not disinfected, it can become an area for pathogen entry that leads to septicemia (Fordyce et al., 2018; Mee, 2008). Naval illness occurs in 5% to 15% of newborn calves, and if left untreated, can lead to reduced growth, joint ill, and other sequela (Mee, 2008). Prevention of naval illness is based on maternity pen hygiene and the amount of time a calf spends in the maternity pen, ensuring successful transfer of passive immunity, and naval antisepsis (Mee, 2008). Naval dipping (antisepsis) promotes the healing of the umbilical stump, prevents infection, and encourages the umbilical tissue to detach from the body (Fordyce et al., 2018). Careful and routine umbilical cord care with an antiseptic and keeping the area in a dry, clean, well-ventilated area can substantially decrease poor health outcomes such as morbidity and mortality in calves (Mee, 2008).

2.2.3 Housing

Satisfactory housing environments for calves provide them with thermal, physical, psychologic, and behavioral comfort that can reduce stress in young calves (Stull and Reynolds, 2008). When housing environments are inadequate, the calf's risk of compromised immune responses, growth rates, and disease increase (Stull and Reynolds, 2008). Housing for pre-weaned calves can vary from group pens or stalls to individual hutches with varying size dimensions. Recommendations by (Stull and Reynolds, 2008) include individuals > 2 months of age need 32 sq. ft. with clean, dry, bedding that allows the calf to have adequate lying time, easy access to feed and water, with good air quality. Additionally, calves should be protected from climate and thermal extremities to ensure safety from injury (Stull and Reynolds, 2008).

2.3 Welfare challenges for surplus calves during marketing and transport

Surplus dairy calves are typically marketed soon after birth in the United States (Shivley et al., 2019). Marketing, herein described as the process of selling / purchasing animals, is a well-known stressor for animals of any age (Bravo et al., 2019); however, it can be particularly stressful for young, vulnerable animals, such as surplus dairy calves (reviewed by Roadknight et al., 2021a). During marketing and road transport, several calf welfare challenges have been identified, including fasting, associated with extended periods without feed; injury, associated with human handling, standing for long periods of time, and bracing against truck movements; and dehydration and disease, associated with suboptimal newborn care, fasting, and pathogen exposure as calves enter and are co-mingled in different environments (Pempek et al., 2017; Roadknight et al., 2021a).

2.3.1 Fasting

During marketing and transport, calves may not have access to feed (e.g., milk) or water for extended periods of time, which presents a high likelihood of welfare compromise for neonatal calves (Roadknight et al., 2021b; Roadknight et al., 2021c). Typically, fasting before and during transport is done to reduce fecal contamination of the transport trailer and thereby increase the efficiency of the transport process. Long periods of fasting and transport can be a stressful experience for cattle of any age (Grandin, 1997). When considering the nutritional needs of neonatal calves, they have very low body fat reserves and are at risk of energy depletion during transport (Bell and Sly, 1979). Plasma glucose concentrations decrease during fasting and may experience hypoglycemia if body energy stores are insufficient or unable to be utilized fast enough to maintain a glycemic status (Roadknight et al., 2021b). Additionally, as stated previously, calves' risks of morbidity and mortality is higher compared to adult cattle, and these risks may be exacerbated when experienced concurrently with the stressors associated with transport, e.g., handling, novelty, reduced opportunities to rest, and fasting (Roadknight et al., 2020).

2.3.2 Injury

Injury of young calves during transport increases because calves have been demonstrated as having a higher incidence of falls during transportation, compared to adult cattle (Cockram and Spence, 2012). Reasons such as the young age of the calves demonstrates an inadequate amount of time for the calves to learn herding and following behaviors that makes them more difficult to handle, especially during loading and unloading (Roadknight et al., 2020). Creatine kinase (CK), a sensitive indicator of muscle fatigue or damage, can increase with transportation. Roadknight et al. (2020) obtained blood samples at slaughterhouses on 4,484 bobby calves, aged approximately 5-14 days old after transportation, fasting, and lairage. This research identified 36% of calves had CK results greater than the young calf CK upper reference level, compared to non-transported calves. Concluding the muscle fatigue or damage occurred during transportation for these young calves.

2.3.3 Dehydration and disease

Previous studies have identified calves having higher packed cell volume **(PCV)** and urea concentrations, indicating dehydration, after transportation (Roadknight et al., 2020; Stafford et al., 2001). Additionally, with increasing distance transported, calves were more likely to show evidence of dehydration (as indicated by high PCV or total protein levels) (Roadknight et al., 2020). Recent studies have found that dehydration in calves on arrival at veal facilities and calf collection centers in Europe is still an ongoing issue, with the prevalence of dehydration ranging from 35 to 70% (Marcato et al., 2020; Pempek et al., 2017; Renaud et al., 2018). Marketing can also increase calves' risk of disease and negatively affect calf welfare because: (1) stress caused by handling may suppress immunity to disease; (2) co-mingling of calves from different dairy farms expose them to new pathogens and bacteria; and (3) calves do not always receive an appropriate quantity and quality of feed and water or in a timely manner while in transit (Wilson et al., 2020a). In conclusion, marketed calves face a variety of challenges that can increase their risk of morbidity and mortality and result in welfare compromise.

2.3.4 Health on arrival at slaughter establishments and calf-raising facilities

Calves arriving at slaughter establishments (England et al., unpublished data) and calf-raising facilities (e.g., veal) often arrive in suboptimal condition (Wilson et al, 2000; Pempek et al., 2017; Renaud et al., 2018). Recent research suggests the majority of bob veal calves (96%) had at least one poor health outcome on arrival at a slaughter establishment in the Midwestern United States (England et al., unpublished data). This study also reported a high prevalence of hypoglycemia (74%), and male (compared to female) calves had 3.1 times greater odds of having hypoglycemia. Because most surplus calves are marketed similarly (independent of their destination), there is evidence that calves entering the formula-fed veal sector also arrive at calf-raising facilities in poor health. For instance, Wilson et al. (2000) conducted a study assessing veal calf condition on arrival at 5 calf-raising facilities; Holstein bull calves were assessed for 16 physical health outcomes, and blood samples were collected within 2 h of arrival to estimate FTPI. Of the 1,179 calves sampled in this study, 17% were dehydrated on arrival; 32% had navel inflammation; 27% were anemic; and 43% did not receive adequate colostrum (Wilson et al., 2000). Nearly two decades later, health concerns in calves on arrival at calf-raising facilities persist. For example, Renaud et al. (2018) evaluated calf condition (n = 4,825) on arrival at a commercial formula-fed veal facility in Ontario, Canada and documented signs of navel inflammation, dehydration, low BCS, and sunken flanks in calves. Further, Pempek et al. (2017) also reported clinical signs of diarrhea (14%), depression (14%), navel inflammation (27%), and dehydration (35%) in calves on arrival at special-fed veal facilities in Ohio. Calves experiencing poor health on arrival is not only a direct calf welfare concern, but also represents important risks for mortality in calves; navel inflammation, dehydration, and the presence of a sunken flank on arrival at calf-raising facilities have been identified as risk factors for early mortality (e.g., mortality within 21 d after arrival to the calf-raising facility).

2.4 Study purpose and hypotheses

The fate of surplus calves has been described as an "ever-present challenge" in a global context (Bolton et al., 2021). However, little research (compared to other food animal industries) has been devoted to understanding and improving the complex animal welfare challenges within the surplus dairy calf industries. There is some evidence that surplus dairy calves are disadvantaged from birth, as they receive suboptimal neonatal care on the dairy farm. In the United States, young calves are typically sold in the first week of life through live auction, co-mingled and aggregated at livestock dealers, during which they are fasted and often transported long distances to slaughter establishments (e.g., bob veal) or calf-raising facilities (e.g., formula-fed veal and dairy beef). Considering the varying prevalence of disease signs on arrival at slaughter establishments and calf-raising facilities, as well as the increased hazard of early mortality, methods to prevent the development of these conditions need to be investigated prior to calves' arrival at their destination. To our knowledge, no research in the United States has investigated calf condition during marketing, particularly on arrival at livestock dealers, to guide future preventative measures to improve calf welfare prior to arrival at their destination.

Thus, our objectives of this study were 1) estimate the prevalence of FTPI and poor health outcomes in calves on arrival to livestock dealers and 2) determine risk factors for poor health outcomes, including sale body weight, sex, and source. We anticipated to observe a moderate to high prevalence of navel inflammation, dehydration, depression, and FTPI among surplus dairy calves on arrival at livestock dealers. We also hypothesized that male surplus dairy calves (compared to female) and calves sourced non-directly from a live auction or livestock market (compared to direct from the dairy farm of birth) would be identified as risk factors for poor health outcomes.

2.5 References

Atkinson, D. J., M. A. G. von Keyserlingk, and D. M. Weary. 2017. Benchmarking passive transfer of immunity and growth in dairy calves. J. Dairy Sci.100(5):3773-3782. https://doi.org/10.3168/jds.2016-11800.

Bell, F. R., and J. Sly. 1979. The metabolic effects of sodium depletion in calves on salt appetite assessed by operant methods. Physiol. J. 295(1):431-443. https://doi.org/10.1113/jphysiol.1979.sp012978.

Bolton, S. E., and M. A. G. von Keyserlingk, Marina A G. (2021). The dispensable surplus dairy calf: Is this issue a "wicked problem" and where do we go from here? Front. Vet. Sci. 8:660934. https://doi.org/10.3389/fvets.2021.660934.

Bravo, V. M., T. G. Knowles, and C. Gallo. 2019. Factors affecting the welfare of calves in auction markets. Animals 9(6):333. https://doi.org/10.3390/ani9060333.

Cockram, M. S., and J. Y. Spence. 2012). The effects of driving events on the stability and resting behaviour of cattle, young calves and pigs. Animal Welfare 21(3):403-417. https://doi.org/10.7120/09627286.21.3.403.

Creutzinger, K., J. Pempek, G. Habing, K. Proudfoot, S. Locke, D. Wilson, and D. Renaud. 2021. Perspectives on the management of surplus dairy calves in the United States and Canada. Front. Vet. Sci. 8:661423. https://doi.org/10.3389/fvets.2021.661453.

Fischer, A. J., Y. Song, Z. He, D. M. Haines, L. L. Guan, and M. A. Steele. 2018. Effect of delaying colostrum feeding on passive transfer and intestinal bacterial colonization in neonatal male Holstein calves. J. Dairy Sci. 101(4):3099-3109. https://doi.org/10.3168/jds.2017-13397.

Fordyce, A. L., L. L. Timms, K. J. Stalder, and H. D. Tyler. 2018. Short communication: The effect of novel antiseptic compounds on umbilical cord healing and incidence of infection in dairy calves. J. Dairy Sci. 101(6):5444-5448. https://doi.org/10.3168/jds.2017-13181.

Godden, S. 2008. Colostrum management for dairy calves. Vet. Clin. North Am. Food Anim. 24(1):19-39. https://doi.org/10.1016/j.cvfa.2007.10.005.

Grandin, T. 1997. Assessment of stress during handling and transport. J. Anim. Sci. 75(1):249-257. https://doi.org/10.2527/1997.751249x.

Grandin, T. 2020. Review of stress and animal welfare by Donald Broom and Ken G. Johnson. Animals 10(2):363. https://doi.org/10.3390/ani10020363.

Hänninen, L., H. Hepola, S. Raussi, and H. Saloniemi. 2008. Effect of colostrum feeding method and presence of dam on the sleep, rest and sucking behaviour of newborn calves. Appl. Anim. Behav. Sci. 112(3):213-222. https://doi.org/10.1016/j.applanim.2007.09.003.

Marcato, F., H. van den Brand, B. Kemp, and K. van Reenen. 2018. Evaluating potential biomarkers of health and performance in veal calves. Front. Vet. Sci. 5:133. https://doi.org/10.3389/fvets.2018.00133.

Mee, J. F. 2008. Newborn dairy calf management. Vet. Clin. North Am. Food Anim. 24(1):1-17. https://doi.org/10.1016/j.cvfa.2007.10.002.

USDA. 2020. Milk production.Accessed Oct. 24, 2022: https://www.nass.usda.gov/Publications/Todays_Reports/reports/mkpr0220.pdf.

Pempek, J., D. Trearchis, M. Masterson, G. Habing, and K. Proudfoot. 2017. Veal calf health on the day of arrival at growers in Ohio. J. Anim. Sci. 95(9):3863-3872. https://doi.org/10.2527/jas2017.1642.

Wilson, D. J., J. Stojkov, D. L. Renaud, and D. Fraser. 2020. Condition of male dairy calves at auction markets. J. Dairy Sci. 103(9):8530-8534. https://doi.org/10.3168/jds.2019-17860.

Renaud, D. L., T. F. Duffield, S. J. LeBlanc, D. F. Kelton, and D. B. Haley. 2017. Calf management risk factors on dairy farms associated with male calf mortality on veal farms. J. Dairy Sci. 101(2):1785-1794. https://doi.org/10.3168/jds.2017-13578.

Renaud, D. L., T. F. Duffield, S. J. LeBlanc, S. Ferguson, D. B. Haley, and D. F. Kelton. 2018. Risk factors associated with mortality at a milk-fed veal calf facility: A prospective cohort study. J. Dairy Sci. 101(3):2659-2668. https://doi.org/10.3168/jds.2017-13581.

Renaud, D. L., M. W. Overton, D. F. Kelton, S. J. LeBlanc, K. C. Dhuyvetter, and T. F. Duffield. 2018. Effect of health status evaluated at arrival on growth in milk-fed veal calves: A prospective single cohort study. J. Dairy Sci. 101(11):10383-10390. https://doi.org/10.3168/jds.2018-14960.

Roadknight, N., N. Courtman, P. Mansell, E. Jongman, S. Clarke-Errey, and A. Fisher. 2020. Blood collection from dairy calves at exsanguination post-slaughter yields similar biochemical and packed cell volume measurements compared with in vivo collection during lairage. Res. Vet. Sci. 130:41-47. https://doi.org/10.1016/j.rvsc.2020.02.013.

Roadknight, N., P. Mansell, E. Jongman, N. Courtman, and A. Fisher. 2021a. Invited review: The welfare of young calves transported by road. J. Dairy Sci. 104(6):6343-6357. https://doi.org/10.3168/jds.2020-19346.

Roadknight, N., P. Mansell, E. Jongman, N. Courtman, D. McGill, G. Hepworth, and A. Fisher. 2021b. Blood parameters of young calves at abattoirs are related to distance transported and farm of origin. J. Dairy Sci. 104(8):9164-9172. https://doi.org/10.3168/jds.2020-19729.

Roadknight, N. W., N. F. Courtman, P. D. Mansell, E. C. Jongman, Z. A. Loh, and A. D. Fisher. 2021c. Biochemistry and hematology reference intervals for neonatal dairy calves aged 5-12 days. Vet. Clin. Pathol. 50(2):278-286. https://doi.org/10.1111/vcp.12955.

Shivley, C. B., J. E. Lombard, N. J. Urie, D. M. Weary, and M. A. G. von Keyserlingk, 2019. Management of preweaned bull calves on dairy operations in the United States. J. Dairy Sci. 102(5):4489-4497. https://doi.org/10.3168/jds.2018-15100.

Stafford, K. J., D. J. Mellor, S. E. Todd, N. G. Gregory, R. A. Bruce, and R. N. Ward. 2001. The physical state and plasma biochemical profile of young calves on arrival at a slaughter plant. NZVJ 49(4):142-149. https://doi.org/10.1080/00480169.2001.36222.

Stull, C., and J. Reynolds. 2008. Calf welfare. Vet. Clin. North Am. Food Anim. 24(1):191-203. https://doi.org/10.1016/j.cvfa.2007.12.001.

USDA-FSIS (U.S. Department of Agriculture Food Safety and Inspection Service). 2020. FY 2020 NRP: Estimated amount of domestically produced meat, poultry, and egg products. Accessed Oct. 18, 2022. https://www.fsis.usda.gov/sites/default/files/media_file/2020-07/2020-nrp_appendix_III.pdf.

VQA (Veal Quality Assurance). 2018. Veal Quality Assurance Certification Resource Manual. Accessed Oct. 24, 2022. https://www.veal.org/wp-content/uploads/2020/11/VQA_Manual_2018_FINAL.pdf.

Wilson, L. L., J. L. Smith, D. L. Smith, D. L. Swanson, T. R. Drake, D. R. Wolfgang, and E. F. Wheeler. 2000. Characteristics of veal calves upon arrival, at 28 and 84 days, and at end of the production cycle. J. Dairy Sci. 83(4):843. https://doi.org/10.3168/jds.s0022-0302(00)74948-4.

Wilson, D. J., D. Canning, T. Giacomazzi, K. Keels, R. Lothrop, D. L. Renaud, N. Sillett, D. Taylor, H. Van Huigenbos, B. Wynands, D. Zuest, and D. Fraser. 2020a. Hot topic: Health and welfare challenges in the marketing of male dairy calves—Findings and consensus of an expert consultation. J. Dairy Sci. 103(12):11628-11635. https://doi.org/10.3168/jds.2020-18438.

Wilson, D. J., J. Stojkov, D. L. Renaud, and D. Fraser. 2020b. Short communication: Condition of male dairy calves at auction markets. J. Dairy Sci. 103(9), 8530-8534. https://doi.org/10.3168/jds.2019-17860.

Wilson, D. J., J. A. Pempek, S. M. Roche, K. C. Creutzinger, S. Locke, G. Habing, K. L. Proudfoot, K. A. George, D. L. Renaud. 2021. A focus group study of Ontario dairy producer perspectives on neonatal care of male and female calves. J. Dairy Sci. 104(5):6080-6095. https://doi.org/10.3168/jds.2020-19507.

Chapter 3. Condition of surplus dairy calves at livestock dealers in Ohio: A cross-sectional study

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3.1 Abstract

Surplus dairy calves are sold soon after birth, often through a live auction or livestock dealer (e.g., a facility where large groups of calves are aggregated) before entering veal or dairy beef production chains in the United States. Our previous work demonstrated veal calves arrive to calf-raising facilities with failed transfer of passive immunity **(FTPI)** and signs of disease, but little is known regarding calf condition on arrival at livestock dealers. The objectives of this cross-sectional study were to 1) estimate the prevalence of FTPI and poor health outcomes in surplus calves at livestock dealers and 2) determine risk factors for poor health, including sale body weight, sex, and source. Two livestock dealers in Ohio were visited 2 to 3 times per week, with approximately 28 calves enrolled in the study per visit for a total of 1,119 calves. One blood sample per calf was obtained to evaluate FTPI by measuring serum total protein levels (using a cutoff < 5.1 g/dL). Calves were clinically evaluated for signs of navel inflammation, depression, dehydration, fever, diarrhea, respiratory disease, and arthritis; health outcomes were dichotomized using clinically relevant cut-points. Descriptive statistics were used to describe the prevalence of calves with poor condition. A multivariable logistic regression model was used to determine if sale body weight (< 40.8 kg vs ≥ 40.8 kg), sex (male vs female), and source (direct from dairy vs. non-direct purchasing from a live auction or livestock dealer) were risk factors for poor health outcomes. Nineteen percent (206/1091) of calves had FTPI, and those purchased directly from the dairy farm were more likely to have FTPI compared to those purchased from live auctions or livestock dealers (OR: 2.25; 95% CI: 1.25 to 4.03; $P = 0.007$). Upon clinical examination, 69.2% (769/1112) of calves were considered dehydrated, 26.3% (293/1112) had navel inflammation, and 7.33% (82/1118) were depressed. Male calves were more likely than female calves to have navel inflammation (OR: 1.86; 95% CI: 1.24 to 2.77; $P = 0.03$) and ocular discharge (OR: 1.95; 95% CI: 0.92 to 4.12; $P = 0.08$). This research highlights the opportunity for continued improvements in colostrum management for female and male surplus dairy calves, and interventions are necessary to reduce the high observed prevalence of dehydration and navel inflammation.

3.2 Introduction

Calves born on dairy farms can either be introduced to the milking herd or sold for other purposes, such as red meat production. In the United States, most calves (predominantly male) are sold from the dairy farm within a week of birth (Shevley et al., reviewed by Creutzinger et al., 2021); this calf population is commonly referred to as "surplus" because these animals exceed the needs of the dairy operation. Surplus calves are typically sold through live auctions, individual livestock dealers (i.e., facilities where large groups of calves are aggregated), or both before entering one of three production chains: “bob” veal (up to 3 weeks of age or 150 pounds; Wilson et al., 2000), “special-fed” veal (approximately 22 weeks of age or 500 pounds; USDA-FSIS, 2013), or dairy beef (12-14 months of age or 1,300 to 1,500 pounds; Creutzinger et al., 2021).

Surplus calf welfare in the veal and dairy beef industries is inextricably linked to the quality of neonatal care calves received on the dairy farm of birth. Colostrum management has been referenced as the most important management practice in determining future calf health and survival (Godden et al., 2019). If colostrum management is inadequate and failed transfer of passive immunity **(FTPI)** occurs, this can increase calves’ risk of pre-weaning morbidity and mortality, the duration and contagiousness of disease, reduce productivity (e.g., growth rates), and increase culling risks (Atkinson et al., 2017). However, there is some evidence that colostrum management practices sometimes differ for male and female calves on the dairy farm of birth, with male calves receiving suboptimal care. For instance, Shively et al. (2019) reported bull calves received 4.8 L of colostrum in the first 24 hours of life, compared to 5.5 L for heifer calves.

Surplus calves are neonates and particularly vulnerable to compromised welfare, compared to adult cattle (reviewed by Roadknight et al., 2021). Calves often face a multitude of challenges during marketing and transport, such as injury, pathogen exposure, fasting, extreme weather conditions, and stress (reviewed by Roadknight et al., 2021). Calves arriving at calf-raising facilities (e.g., veal) often arrive in suboptimal condition (Wilson et al, 2000; Pempek et al., 2017; Renaud et al., 2018). Recent research suggests the majority of bob veal calves (96%) had at least one poor health outcome on arrival at a slaughter establishment in the Midwestern United States (England et al., unpublished data). This study also reported a high prevalence of hypoglycemia (74%), and male (compared to female) calves had 3.1 times greater odds of having hypoglycemia.

To date, studies on surplus calf welfare have mainly focused on neonatal care practices or calf health on arrival at slaughter establishments or calf-raising facilities. To our knowledge, no studies in the United States have been performed to assess calf condition during marketing on arrival at livestock dealers. By assessing calf condition during marketing, we can identify possible health concerns at this point in the production chain and target interventions to reduce morbidity and mortality before calves enter veal or dairy beef industries. Thus, the objectives of this cross-sectional study were to: 1) estimate the prevalence of FTPI and poor health outcomes in calves on arrival at livestock dealers, and 2) determine risk factors for poor health outcomes, including sex, source, and sale body weight.

3.3 Materials and Methods

3.3.1 Animals, handling, and facilities

All procedures described herein were in accordance with the guidelines set forth by The Ohio State University's Institutional Animal Care and Use Committee (Animal Use Protocol 2021A00000047). Two livestock dealers responsible for purchasing and selling surplus dairy calves were visited 2 to 3 times per week between May and September 2021 (i.e., Facility 1 and Facility 2). Both facilities were located in Northeastern OH, approximately 177 km from The Ohio State University. Individual dairy producers routinely dropped off individual or small groups of calves daily, and facilities continuously received new calf groups throughout the day. Individual calf weights were obtained and recorded at Facility 1. Group calf weights were obtained during sale at Facility 2; however, this was not always routinely recorded. Facility 1 was a naturally ventilated barn, with approximately (20) group pens; calves were able to touch calves from other pens through gate partitions. Facility 1 did not provide access to feed and water if calves were purchased and sold the same day; however, although rare, if calves were held at the facility over night, they were offered milk replacer via nipple buckets twice daily. This facility had sawdust bedding substrate. Facility 2 was also a naturally ventilated barn, with straw bedding substrate. Calves were group housed in two separate pens, and each pen had one water trough available. Pens were separated by a metal gate through which calves had contact with other calves in the adjacent pen through horizontal metal partitions. Hard copies of written records were obtained from personnel at Facilities 1 and 2, which included information on calf source (i.e., name of dairy farm of birth or live auction or livestock dealer facility), calf identification number, sale weight, and sex. Calf age was not available, as this information was not recorded by the livestock dealers.

3.3.2 Clinical health examination

To ensure a representative sample of the cohort, i.e. the group of calves arriving at Facilities 1 and 2 on observation days, systematic random sampling was utilized to select calves for enrollment in this study. Approximately 28 calves were enrolled in the study per day (n = 1,063 calves total). Study personnel (1 postdoctoral scholar; 1 research associate; 1 veterinary student; 1 graduate student; and 2 undergraduate students with extensive experience handling and assessing calf health performed all aspects of data collection and received 1 wk of training by the Principal Investigators (1 animal welfare scientist; 1 veterinarian and epidemiologist) prior to the onset of the study.

The two members of the research team completed all clinical health examinations, using a standardized health scoring system adapted from previous validated studies with young calves (Pempek et al., 2019). Prior to the onset of the study, research staff assessed the health of 36 calves to ensure consistency between observers for all health outcomes (inter-rater reliability: 92.8%). Health examinations included the evaluation for fever (≥ 39.4°C), depression (4-point scale, (Pempek et al., 2019) respiratory disease (4-point scale for ocular and nasal discharge and ear droop; (McGuirk & Peek, 2014), broken ribs or tail (2-point scale), arthritis (4-point scale; (Garcia et al., 2022), fecal consistency (2-point scale; adapted from (McGuirk, 2008), navel inflammation (4-point scale; (Pempek et al., 2017), and dehydration (skin tent test, 4-point scale; Garcia et al., 2022), as depicted in Table 3.1 below. If a calf was severely depressed (depression score = 3) and unable to rise, only non-invasive aspects of the clinical health examination were performed; blood samples and rectal temperature were not collected (n = 6 calves). Scoring systems and definitions for each health outcome are further described in Table 3.1.

3.3.3 Blood collection, handling, and processing

One blood sample per calf was obtained to evaluate transfer of passive immunity **(TPI)** by measuring serum total protein. Blood samples were obtained from the jugular vein collected into 10-mL vacuum tubes without anticoagulant (BD Vacutainer® Red Top Blood Collection Tubes, Becton Dickinson, Franklin Lakes, NJ). Blood samples were placed into a cooler with ice packs, where they remained during transport to The Ohio State University for serum total protein **(STP)** measurements using the following categories: excellent TPI (≥ 6.2 g/dL serum total protein concentration), good TPI (5.8 to 6.1 g/dL), fair TPI (5.1 to 5.7 g/dL), and poor or FTPI (< 5.1 g/dL) (Lombard et al., 2020). Samples were centrifuged at 3,500 RPM (1,180 x *g*) for 10 min, then transferred via a disposable plastic pipette onto a DD-2 Digital-Dairy Refractometer (MISCO; Solon, OH) to evaluate STP.

3.3.4 Statistical analysis

Calf assessment data was entered manually into Microsoft Excel (Microsoft Corp., Redmond, WA) and checked for errors and completeness. Descriptive statistics were used to describe the prevalence of calves with poor health outcomes on arrival at livestock dealer facilities. Health assessment scores were considered clinically "normal" if broken ribs or tail score = 0; dehydration score = 0; depression score = 0 or 1; fecal score = 0; STP ≥ 5.1 g/dL; rectal temperature < 39.4°C; joint score = 0 or 1; navel score = 0 or 1; and eyes, ears, or nose score = 0 or 1. Calves were considered to have "poor health" outcomes if broken ribs or tail score = 1; dehydration score = 1, 2, or 3 (any dehydration); dehydration score = 2 or 3 (moderate to severe dehydration) depression score = 2 or 3; fecal score = 1; STP < 5.1g/dL; rectal temperature ≥ 39.4°C; blood glucose < 4.95 mmol/L; joint score = 2 or 3; navel score = 2 or 3; and eyes, ears, or nose score = 2 or 3. Table 3.2 summarizes the clinically relevant cutoff values for each variable. All clinical health assessment scores were dichotomized for analysis. The prevalence of poor health outcomes among surplus calves was calculated as the total number calves having a particular poor health outcome over the total sampled. The SURVEYFREQ procedure of SAS (Version 9.4; SAS Institute Inc., Cary, NC) was used to produce prevalence estimates and 95% confidence intervals **(CI)**, and the EXACT statement was specified when prevalence estimates were < 5%.

Complete data were available for 839 calf assessments. Mixed logistic regression models (PROC GLIMMIX, SAS, Version 9.4) were built to determine possible associations between independent variables and the dichotomized dependent health outcome variables (FTPI, diarrhea, navel inflammation, ocular discharge, ear droop, arthritis, depression, fever, any dehydration, and moderate to severe dehydration), with calf source included in the model as a random effect. Because the prevalence of nasal discharge and broken ribs or tail was < 1.0% on arrival at livestock dealers, these variables were excluded from model building procedures. Independent variables related to calf characteristics were all dichotomous and included sale body weight dichotomized at the median sale body weight (< 40.8 kg vs ≥ 40.8 kg), sex (male vs female), and whether calves were sold directly from the dairy farm of birth or were received from a live auction or another livestock dealer (direct vs non-direct purchasing). First, univariable models were constructed; individual independent variables that were associated with a particular health outcome based on a liberal *P*-value cut-point of 0.2 were then offered to a multivariable model. Variables with a non-significant association

($P < 0.05$) were removed from the model using backward stepwise elimination. Significant differences were declared at $P \leq 0.05$ and a trend at $0.05 > P \leq 0.10$.

3.4 Results

3.4.1 Demographics

The majority of surplus calves were male (78%, 826/1063), and 22% (237/1063) were female. The average sale body weight of male and female calves was 40.6 (SD 7.07) and 39.1 (SD 6.46) kg, respectively, on arrival at the livestock dealer. Source information was available for 948 calves, indicating calves were purchased from 180 different locations. Most calves (65.5%; 621/948) were purchased directly from the dairy farm of birth, but approximately one-third (36.6%; 327/948) were sourced from either a live auction or another livestock dealer, indicating this was at least their second sale. Approximately 69% (459/668) of male calves were purchased directly from the dairy farm of birth, compared to 58% (130/224) of female calves.

3.4.2 Prevalence of health outcomes on arrival

Upon clinical examination, 69.2% (95% CI: 66.4 to 71.9%) of calves were considered dehydrated using a skin tent test **(Figure 3.1)**. However, only 2.60% (95% CI: 1.75 to 3.72%) were moderately to severely dehydrated on arrival at the livestock dealer. Approximately one out of every four calves 26.3% (95% CI: 23.8 to 28.9%) had navel inflammation, and 7.33% (95% CI: 5.80 to 8.87%) were depressed. Relatively few calves had signs of respiratory disease; 6.7% (95% CI: 5.2 to 8.2%) of calves had ocular discharge, 1.16% (95% CI: 0.62 to 1.98%) had an ear droop, and 0.63% (95% CI: 0.25 to 1.28%) had nasal discharge. Additionally, 13.1% (95% CI: 11.1 to 15.1%) of calves had diarrhea, 21.9% (95% CI: 19.4 to 24.3%) had a fever, 1.35% (95% CI: 0.76 to 2.21%) had arthritis, and less than 1% (0.55%; 95% CI: 0.20 to 1.19%) had broken ribs or a broken tail. According to recent consensus recommendations for calf-level TPI (Lombard et al., 2020), 43.1% (470/1091) of calves had excellent TPI, 16.7% (182/1091) had good TPI, 21.4% (233/1091) had fair TPI, and 18.9% (206/1091) had poor TPI or FTPI.

Table 3.3 shows the number and percentage of female and male calves with poor health outcomes on arrival at livestock dealers. Thirty-six percent (83/233) of female calves had excellent TPI, 20.2% (47/233) had good TPI, 27.5% (64/233) had fair TPI, and 16.7% (39/233) had FTPI. Comparatively, forty-three percent (349/809) of male calves had excellent TPI, 15.6% (126/809) had good TPI, 20.6% (167/809) had fair TPI, and 20.6% (167/809) had FTPI.

3.4.3 Risk factors for poor health outcomes

Male calves had nearly twice the odds of having navel inflammation (OR: 1.86; 95% CI: 1.24 to 2.77; $P = 0.003$) and ocular discharge (OR: 1.95; 95% CI: 0.92 to 4.12; $P = 0.08$), compared to female calves. Calf sex, however, was not associated with FTPI (OR: 0.94; 95% CI: 0.60 to 1.47%; $P = 0.77$), and no other health outcome variables were associated with calf sex. This might suggest that male calves are housed in suboptimal conditions compared to female calves, particularly on the dairy.

Calves purchased directly from the dairy farm of birth were more likely to have FTPI (OR: 2.25; 95% CI: 1.25 to 4.04; $P = 0.007$) and clinical signs of diarrhea (OR: 2.31; 95% CI: 1.27 to 4.20; $P = 0.006$), compared to non-direct purchasing through a live auction or livestock dealer. Calves purchased from a live auction or other livestock dealer also had lower odds of depression (OR: 0.39; 95% CI: 0.18 to 0.81; *P* = 0.01). Source was not associated with dehydration (OR: 1.09; 95% CI: 0.60 to 1.97; *P* = 0.77).

Calf sex was associated (*P* = 0.004) with sale body weight, with females lower in body weight compared to males. Low sale body weight (< 40.8 kg) was a risk factor for FTPI (OR: 1.63; 95% CI: 1.11 to 2.38%; *P* = 0.01) and dehydration (OR: 1.83; 95% CI: 1.33 to 2.53; *P* = 0.0002).

3.5 Discussion

The objectives of this study were two-fold: 1) to estimate the prevalence of FTPI and poor health outcomes in calves on arrival at livestock dealers; and 2) to determine risk factors for poor health outcomes, including sex, source, and sale body weight. Approximately one out of every five surplus dairy calves had FTPI, with approximately 43% having suboptimal TPI according to recent standards (Lombard et al., 2020). The most common clinical health concerns observed among calves on arrival at the livestock dealer were dehydration (69.2%) and naval inflammation (26.3%).

Approximately one-fourth of surplus dairy calves (male and female) in our study had FTPI. The prevalence of FTPI for male calves was numerically higher than for female calves (20.6 vs 16.7%, respectively); however, regression analysis did not indicate an association between calf sex and FTPI. Neonatal calf care is essential for calf survival and productivity, and one of the most critical aspects is colostrum management (Godden, 2008). Pempek et al. (2017) assessed the condition of formula-fed veal calves on arrival at calf-raising facilities in Ohio and documented a 6 and 22% FTPI prevalence when using STP cut-points < 5.5 g/dL and < 6.0 g/dL, respectively. Other FTPI estimates observed in surplus dairy calf populations range from 12% (Wilson et al., 2020b) to 43% (Wilson et al., 2000). In comparison, Shively et al. (2018) reported a 12.1% FTPI prevalence in heifer calves (n = 1,972 calves). Our estimate of FTPI prevalence, particularly for male calves, is approximately double current recommendations for FTPI in calf populations (i.e., 10% of calves with STP values < 5.1 g/dL; Lombard et al., 2020).

Low sale body weight and direct purchasing from the dairy farm of birth were identified as risk factors for FTPI. Previous research has identified low body weight on arrival at calf-raising facilities as a significant predictor of reduced average daily gain and early mortality in veal calves (Renaud et al., 2018). The sale of surplus dairy calves is based on calf body weight and, in the current economic climate, only generates a small income for dairy producers (Winder et al., 2016; reviewed by Creutzinger et al., 2021). It is possible that dairy producers prioritized higher-quality resources, such as colostrum, to larger calves that may be more apt to enter the formula-fed veal or dairy beef sectors, compared to smaller calves that may enter the bob veal sector. We did not anticipate that direct purchasing from the dairy farm of birth would be identified as a risk factor for FTPI. The geographical location of the livestock dealers might have influenced this finding; an abattoir harvesting large numbers of bob veal calves was in the same county as the 2 livestock dealers. Because of their proximity to the abattoir, both livestock dealers would aggregate cohorts of calves destined for bob veal, and one dealer would deliver the calf cohorts to the abattoir weekly. Although we do not know the calves' destination in our study, we speculate that this might have influenced the prevalence of

FPTI among calves purchased directly from the dairy farm, as it might be more timely for producers to routinely deliver to the livestock dealer instead of the abattoir.

Most calves were mildly dehydrated on arrival at the livestock dealer in this study. We also chose to estimate any level (e.g., mild, moderate, severe) of dehydration, as mild dehydration might also influence animal welfare through calves experiencing a negative affective state; for example, it is likely that calves feel thirsty before the onset of clinical signs of dehydration. Comparable to our study, Wilson et al. (2000) assessed calf condition (n = 758) on arrival at a veal calf-raising facility and reported 61.3% of calves were dehydrated, using eye and skin indicators (i.e., skin tent ≥ 2 sec) of dehydration. However, Pempek et al. (2017) reported 35.1% of formula-fed veal calves (n = 400) were dehydrated on arrival at the calf-raising facility using a skin tent test > 4 seconds, indicative of moderate to severe dehydration. Moderate to severe dehydration is an animal welfare concern, as it is associated with thirst, dizziness, weakness, or lethargy (Kells et al., 2020). Our comparable estimate for moderate to severe dehydration using a skin tent test ≥ 4 seconds was significantly lower (2.60%). In this study, calf health was assessed earlier in the production chain (on arrival at livestock dealers), whereas previous studies assessed calf health on arrival at calf-raising facilities. We suspect, since calves are not typically provided milk and / or water during marketing unless they are retained overnight, that the prevalence of dehydration would most likely increase post-assessment.

Calves can be fasted without food or water for up to 28 consecutive hours during road transportation in the United States (49 USC 80502), increasing calves' risk of hypoglycemia or dehydration, respectively, during transit. However, in Canada, new regulations limit transport duration to 12 consecutive hours and state that calves shipped to live auction or livestock dealers must be 9 days of age or older (CFIA, 2019). Considering calf transport outside of North America, New Zealand and the European Union require that calves be a minimum age of 4 and 10 d, respectively, and also require the calves' navels be healed and dry before transportation (reviewed by Creutzinger et al., 2021). During marketing at a live auction or livestock dealer, calves will be transported at least once more and sometimes long distances to their destination, only exacerbating their current condition. Considering our results, because the majority of calves were at least mildly dehydrated on arrival at livestock dealers, we strongly recommend all marketing establishments have water or oral electrolyte solutions accessible, regardless of calves' destination or if they will be retained at the facility overnight. Although challenging, given the disaggregated nature of the current calf production chain, we encourage more longitudinal studies to assess changes in calf condition from the dairy farm of birth on through to the calves' destination.

Approximately one out of every four calves (26%) had navel inflammation in our study, and male had nearly twice the odds of having navel inflammation compared to females. Comparatively, Wilson et al. (2020) reported 12% of male dairy calves had navel inflammation during marketing at live auctions in British Columbia, Canada. Navel inflammation is considered painful, as calves with navel inflammation spend less time lying than healthy calves (Studds et al., 2018). Currently, antiseptic compounds such as 7% iodine or 4% chlorhexidine are recommended as best practice to clean, sanitize, and promote healing of the umbilical stump (Robinson et al., 2015), but it is unclear if such practices are routinely being followed on the dairy farm of birth for surplus calves. Because male calves also had greater odds of ocular discharge, this finding might suggest different housing on the dairy farm of birth for male and female calves. It is common for males and females to be housed in separate locations on the dairy, and it is possible that housing provided for male calves is not as sanitary or well ventilated compared to housing for female heifer calves. Future research is warranted to identify if housing or navel care practices for male calves on the dairy farm of birth contributes to poor health outcomes, such as ocular discharge or navel inflammation.

One possible limitation of this study is that data for STP levels or rectal temperature were missing for calves experiencing very poor welfare (e.g., moribund, unable to rise); criteria were established to exclude calves that were severely compromised in this study. Another possible limitation is this study's the lack of breed data. Crossbreed (compared to purebred dairy) calves might produce a greater economic return for dairy producers and, thus, dairy producers may prioritize higher quality resources, such as colostrum, for crossbreed calves. Future research is warranted to investigate possible differences in calf health due to breed. Lastly, measures to elucidate calves' affective state were not included in this study. By investigating the mental and emotional state of the animal, this would lead to a more wholistic assessment of the welfare of surplus dairy calves, particularly considering calf hunger and thirst during fasting.

3.6 Conclusions

To our knowledge, this study is the first to describe the prevalence of poor health outcomes and the associated risk factors in surplus dairy calves on arrival at livestock dealers in the United States. Approximately one out of every five surplus dairy calves had FTPI, with 40% having suboptimal TPI. This finding highlights the opportunity for continued improvements in colostrum management for female and male surplus dairy calves. Dehydration (69.2%) and navel inflammation (26.2%) were the most prevalent heath concerns, and male calves had greater odds of having navel inflammation and ocular discharge. This finding suggests possible discrepant housing or navel care practices for female and male calves on the dairy farm of birth, and we suggest more research to better understand neonatal care and strategies to implement best management practices for male surplus dairy calves. Lastly, interventions are necessary to reduce the high observed prevalence of dehydration. We recommend the provision of oral electrolyte solutions or water on the dairy farm of birth to condition young calves for marketing. We also strongly encourage marketing facilities, such as live auctions or livestock dealers, to also begin offering fluids to mitigate dehydration.

3.7 Acknowledgements

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Table 3.1. Description of scoring criteria used to evaluate calves for clinical signs of respiratory infection (as indicated by ocular and nasal discharge and ear droop), broken tail or ribs, arthritis (joint inflammation), diarrhea, navel inflammation, dehydration, and depression on arrival at livestock dealers in Ohio

Variable	Score			
	0	1	2	3
Ocular discharge	Normal	Small amount of unilateral ocular discharge	Moderate amount of bilateral ocular discharge	Heavy bilateral ocular discharge
Ear droop	Normal	Ear flick or head shake	Slight unilateral droop	Head tilt or bilateral droop
Nasal discharge	Normal serous discharge	Small amount of unilateral cloudy discharge	Bilateral, cloudy or excessive mucus discharge	Copious bilateral mucopurulent discharge
Broken ribs or tail	No broken rib(s) or tail	Presence of broken rib(s) or tail	-	-
Arthritis	No swelling; Not warm or painful	Slight swelling; Not warm or painful	Swelling with pain or heat; Slight lameness	Swelling with severe pain, heat and lameness
Diarrhea	Normal, semi-formed, pasty, or loose but stays on top of bedding	Watery, sifts through bedding	-	-
Navel inflammation	Normal (pencil size); No heat, swelling, or discharge	Bigger than normal (width of the pointer finger); No heat, swelling, or discharge	Bigger than normal (width of the pointer and middle fingers combined); Slight pain or moisture	Bigger than normal (width of the pointer, middle, and ring fingers combined); Heat, pain, or malodorous discharge
Dehydration	Normal; Eyes are bright, and skin feels pliable	Mild dehydration; Slight loss of skin elasticity; Skin tent $\leq$3 s; Eyes not recessed into orbit	Moderate dehydration; Skin tent >3 s but <10 s; Eyes slightly recessed into orbit	Severe dehydration; Skin tent >10 s; Eyes markedly recessed into orbit
Depression	Normal; No signs of depression	Mild depression; Calf suckles but not vigorously	Moderate depression; Calf is able to stand, but suckling is weak or disorganized	Severe depression; Calf unable to stand or suckle

Table 3.2. Clinically relevant cut points for health parameters assessed in calves on arrival at 2 livestock dealers in Ohio

Variable	Normal Health Outcome	Poor Health Outcome
Rectal temperature	< 39.4°C	≥ 39.4°C
Ocular discharge	0 or 1	2 or 3
Ear droop	0 or 1	2 or 3
Nasal discharge	0 or 1	2 or 3
Broken ribs or tail	0	1
Arthritis	0 or 1	2 or 3
Diarrhea	0	1
Navel inflammation	0 or 1	2 or 3
Any dehydration	0	1, 2, or 3
Moderate / severe dehydration	0 or 1	2 or 3
Depression	0	1, 2, or 3
Failed Transfer of Passive Immunity	≥ 5.1 g/dL	< 5.1 g/dL

Table 3.3. Number and percentage of female and male calves with poor health outcomes from a sample of 1,119 surplus dairy calves during marketing at livestock dealers in Ohio

	Female			Male		
Health Outcome	Total Animals	No.	%	Total Animals	No.	%
Any dehydration	236	161	68.2	824	588	71.3
Moderate / severe dehydration	236	7	2.97	825	19	2.30
Navel inflammation	237	42	17.7	822	241	29.3
Fever	237	53	22.4	822	188	22.9
FTPI	233	39	16.7	809	167	20.6
Diarrhea	237	28	11.8	825	109	13.2
Depression	237	8	3.38	825	68	8.24
Ocular discharge	237	9	3.80	826	64	7.75
Arthritis	237	3	1.27	823	12	1.46
Ear droop	237	2	0.84	826	10	1.21
Nasal discharge	237	1	0.42	826	5	0.61
Broken ribs or tail	235	1	0.43	824	5	0.61

Table 3.4. Univariable logistic regression model for poor health outcomes for surplus dairy calves on arrival at livestock dealers in Ohio, including variables (sale body weight, sex, source) associated at $P < 0.2$

Health Outcome	Variable	Odds Ratio	95% CI	*P*-value
FTPI	Source			
	Auction / dealer	0.46	0.26 to 0.82	0.009
	Dairy farm	Referent		
	Body weight			
	≥ 40.8 kg	0.63	0.43 to 0.92	0.02
	< 40.8 kg	Referent		
Navel inflammation	Sex			
	Female	0.54	0.36 to 0.81	0.003
	Male	Referent		
Eye discharge	Sex			
	Male	1.95	0.92 to 4.12	0.08
	Female	Referent		
	Body weight			
	≥ 40.8 kg	0.61	0.35 to 1.1	0.08
	< 40.8 kg	Referent		
Diarrhea	Source			
	Auction / dealer	0.43	0.24 to 0.79	0.006
	Dairy farm	Referent		
Depression	Sex			
	Male	2.05	0.93 to 4.51	0.07
	Female	Referent		
	Source			
	Auction / dealer	0.39	0.18 to 0.81	0.01
	Dairy farm	Referent		
Arthritis	Source			
	Auction / dealer	0.33	0.07 to 1.66	0.18
	Dairy farm	Referent		
Any dehydration	Body weight			
	≥ 40.8 kg	0.55	0.40 to 0.75	0.0002
	< 40.8 kg	Referent		

Table 3.5. Multivariable logistic regression model for poor health outcomes for surplus dairy calves on arrival at livestock dealers in Ohio, including variables (sale body weight, sex, source) associated at $P < 0.05$

Health Outcome	Variable	Odds Ratio	95% CI	*P*-value
FTPI	Source			
	Auction / dealer	0.45	0.25 to 0.80	0.007
	Dairy farm	Referent		
	Body weight			
	≥ 40.8 kg	0.62	0.42 to 0.90	0.01
	< 40.8 kg	Referent		
Depression				
	Source			
	Auction / dealer	0.39	0.18 to 0.81	0.01
	Dairy farm	Referent		

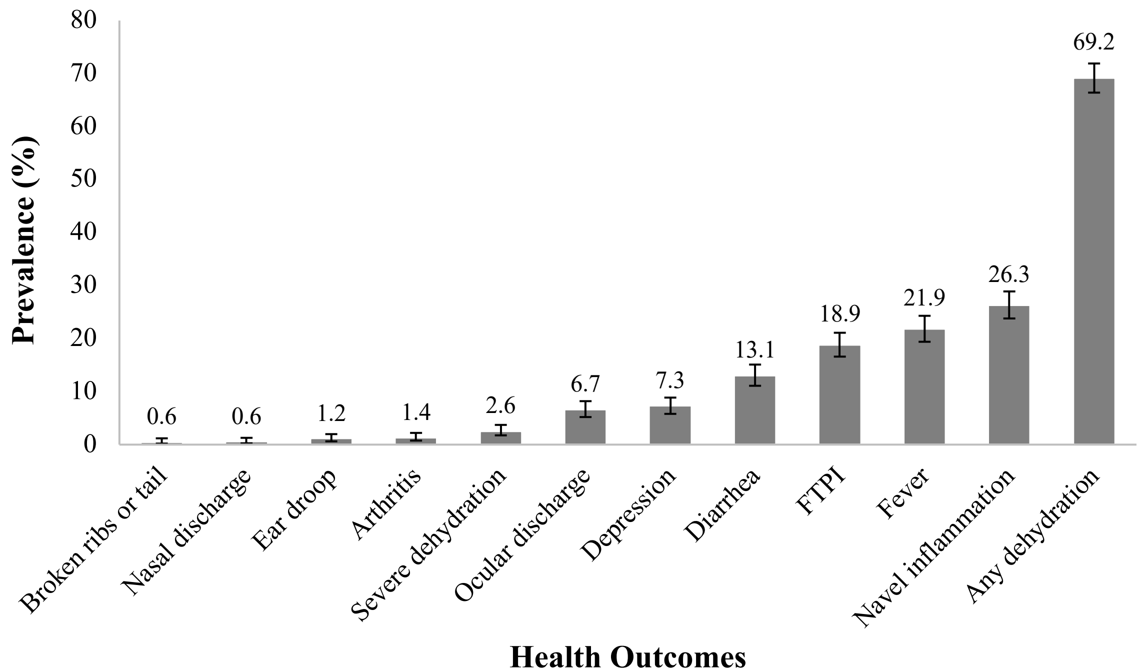

Figure 3.1. Prevalence of suboptimal health outcomes in surplus dairy calves on arrival at livestock dealers in Ohio

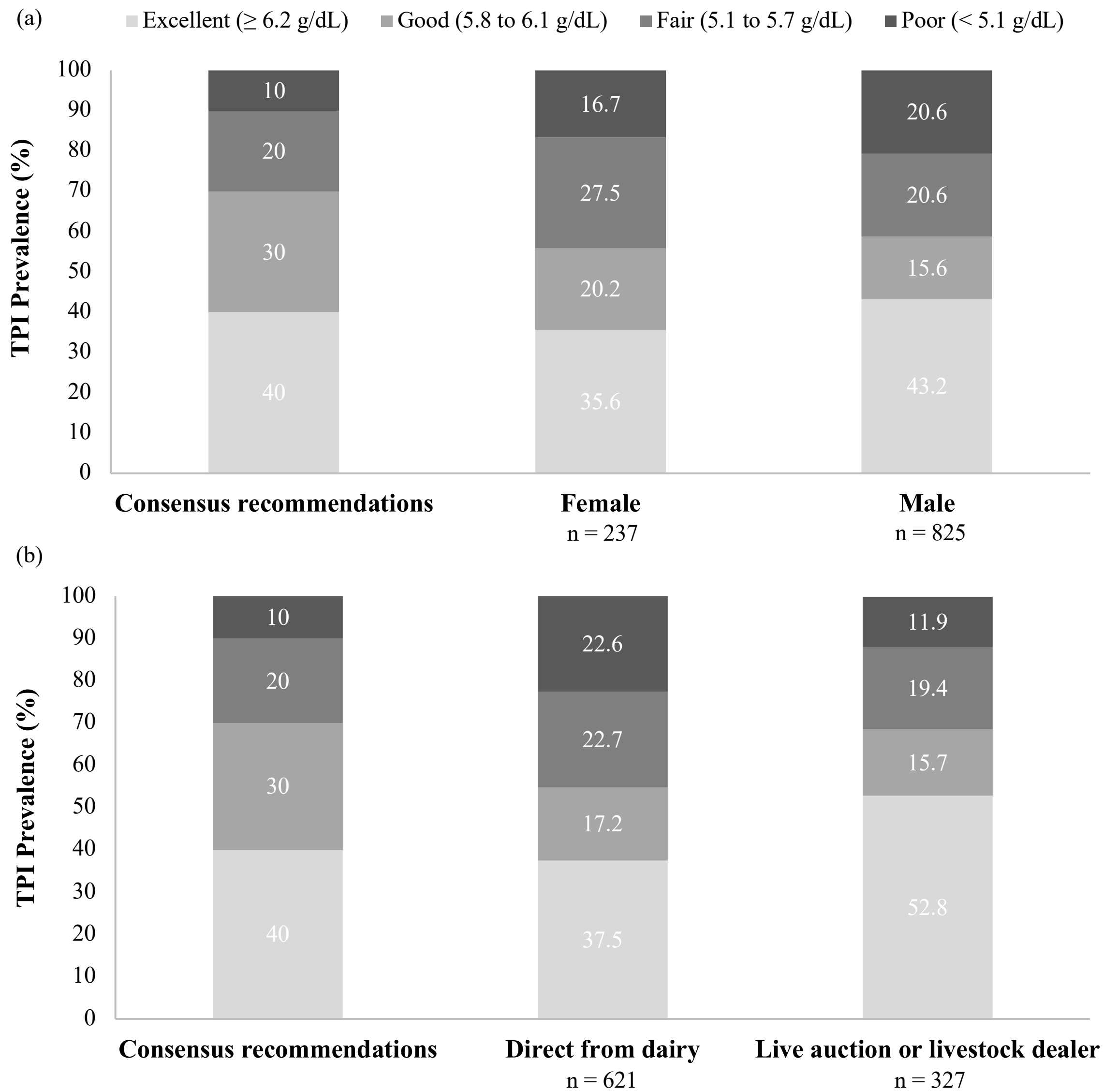

Figure 3.2. Proportion of male and female surplus calves (a) from different sources (b) with excellent (≥ 6.2 g/dL), good (5.8 to 6.1 g/dL), fair (5.1 to 5.7 g/dL), and poor (< 5.1 g/dL) serum total protein values, in reference to consensus serum total protein and percentage of calves recommended in each transfer of passive immunity **(TPI)** category

3.8 References

Atkinson, D. J., M. A. G. von Keyserlingk, and D. M. Weary. 2017. Benchmarking passive transfer of immunity and growth in dairy calves. J. Dairy Sci. 100(5):3773-3782. https://doi.org/10.3168/jds.2016-11800.

CFIA (Canadian Food Inspection Agency). 2019. Canada Gazette, Part 2, Volume 153, Number 4: Regulations Amending the Health of Animals Regulations. Accessed October 18, 2022. http://www.gazette.gc.ca/rp-pr/p2/2019/2019-02-20/html/sor-dors38-eng.html.

Creutzinger, K., J. Pempek, G. Habing, K. Proudfoot, S. Locke, D. Wilson, and D. Renaud. 2021. Perspectives on the Management of Surplus Dairy Calves in the United States and Canada. Front. Vet. Sci. 8:661435. https://doi.org/10.3389/fvets.2021.661453.

Garcia, J., J. Pempek, M. Hengy, A. Hinds, D. Diaz-Campos, and G. Habing. 2022. Prevalence and predictors of bacteremia in dairy calves with diarrhea. J. Dairy Sci. 105(1):807-817. https://doi.org/10.3168/jds.2020-19819.

Godden, S. 2008. Colostrum management for dairy calves. Vet. Clin. North Am. Food Anim. 24(1):19-39. https://doi.org/10.1016/j.cvfa.2007.10.005.

Godden, S. M., J. E. Lombard, and A. R. Woolums. 2019. Colostrum management for dairy calves. Vet. Clin. North Am. Food Anim. 35(3):535-556.

Kells, N. J., N. J. Beausoleil, C. B. Johnson, J. P. Chambers, C. O'Connor, J. Webster, R. Laven, and N. Cogger. 2020. Indicators of dehydration in healthy 4- to 5-day-old dairy calves deprived of feed and water for 24 hours. J. Dairy Sci. 103(2):11820-11832. https://doi.org/10.3168/jds.2020-18743.

Lombard, J., N. Urie, F. Garry, S. Godden, J. Quigley, T. Earleywine, S. McGuirk, D. Moore, M. Branan, M. Chamorro, G. Smith, C. Shivley, D. Catherman, D. Haines, A. J. Heinrichs, R. James, J. Maas, and K. Sterner. 2020. Consensus recommendations on calf- and herd-level passive immunity in dairy calves in the United States. J. Dairy Sci. 103(8):7611-7624. https://doi.org/10.3168/jds.2019-17955.

McGuirk, S. M. 2008. Disease management of dairy calves and heifers. Vet. Clin. North Am. Food Anim. 24(1):139-153. https://doi.org/10.1016/j.cvfa.2007.10.003.

McGuirk, S. M., and S. F. Peek. 2014. Timely diagnosis of dairy calf respiratory disease using a standardized scoring system. Anim. Health Res. Rev. 15(2):145-147. https://doi.org/10.1017/S1466252314000267.

Pempek, J. A., L. R. Watkins, C. E. Bruner, and G. G. Habing. 2019. A multisite, randomized field trial to evaluate the influence of lactoferrin on the morbidity and mortality of dairy calves with diarrhea. J. Dairy Sci. 102(10):9259-9267. https://doi.org/10.3168/jds.2019-16476.

Pempek, J., D. Trearchis, M. Masterson, G. Habing, and K. Proudfoot. 2017. Veal calf health on the day of arrival at growers in Ohio. J. Anim. Sci. 95(9):3863-3872. https://doi.org/10.2527/jas2017.1642.

Renaud, D. L., T. F. Duffield, S. J. LeBlanc, S. Ferguson, D. B. Haley, and D. F. Kelton. 2018. Risk factors associated with mortality at a milk-fed veal calf facility: A prospective cohort study. J. Dairy Sci. 101(3):2659-2668. https://doi.org/10.3168/jds.2017-13581.

Renaud, D. L., M. W. Overton, D. F. Kelton, S. J. LeBlanc, K. C. Dhuyvetter, and T. F. Duffield. 2018. Effect of health status evaluated at arrival on growth in milk-fed veal calves: A prospective single cohort study. J. Dairy Sci. 101(11):10383-10390. https://doi.org/10.3168/jds.2018-14960.

Roadknight, N., P. Mansell, E. Jongman, N. Courtman, and A. Fisher. 2021. Invited review: The welfare of young calves transported by road. J. Dairy Sci. 104(6):6343-6357. https://doi.org/10.3168/jds.2020-19346.

Robinson, A. L., L. L. Timms, K, J. Stalder, and H. D. Tyler. 2015. Short communication: The effect of 4 antiseptic compounds on umbilical cord healing and infection rates in the first 24 hours in dairy calves from a commercial herd. J. Dairy Sci. 98(8):5726-5728. https://doi.org/10.3168/jds.2014-9235.

Shivley, C. B., J. E. Lombard, N. J. Urie, D. M. Weary, and M. A. G. von Keyserlingk, 2019. Management of preweaned bull calves on dairy operations in the United States. J. Dairy Sci. 102(5):4489-4497. https://doi.org/10.3168/jds.2018-15100.

Shivley, C. B., J. Lombard, N. J. Urie, D. M. Haines, R. Sargent, C. A. Kopral, T. J. Earleywine, J. D. Olson, and F. B. Garry. 2018. Preweaned heifer management on US dairy operations: Part II. Factors associated with colostrum quality and passive transfer status of dairy heifer calves. J. Dairy Sci. 101(10):9185-9198. https://doi.org/10.3168/jds.2017-14008.

Studds, M. J., L. L. Deikun, D. E. Sorter, J. A. Pempek, and K. L. Proudfoot. 2018. Short communication: The effect of diarrhea and navel inflammation on the lying behavior of veal calves. J. Dairy Sci. 101(12):11251-11255. https://doi.org/10.3168/jds.2018-15003.

United States Code. Title 49. Transportation animals. Accessed Oct. 18, 2022. https://www.animallaw.info/statute/us-food-animal-twenty-eight-hour-law.

USDA-FSIS (U.S. Department of Agriculture Food Safety and Inspection Service). 2020. FY 2020 NRP: Estimated amount of domestically produced meat, poultry, and egg products. Accessed Oct. 18, 2022. https://www.fsis.usda.gov/sites/default/files/media_file/2020-07/2020-nrp_appendix_III.pdf.

Wilson D. J., J. Stojkov, D. L. Renaud, and D. Fraser. 2020. Risk factors for poor health outcomes for male dairy calves undergoing transportation in western Canada. Can. Vet. J. 61(12):1265-1272. PMCID: PMC7659877.

Wilson, L. L., J. L. Smith, D. L. Smith, D. L. Swanson, T. R. Drake, D. Wolfgang, and E. F. Wheeler. 2000. Characteristics of veal calves upon arrival, at 28 and 84 says, and at end of the production cycle. J. Dairy Sci. 83(4):843-854. https://doi.org/10.3168/jds.s0022-0302(00)74948-4.

Winder, C. B., D. F. Kelton, and T. F. Duffield. 2016. Mortality risk factors for calves entering a multi-location white veal farm in Ontario, Canada. J. Dairy Sci. 99(12):10174-10181. https://doi.org/10.3168/jds.2016-11345.

Chapter 4: Overall conclusions and future directions

This thesis began with a review of the concept of animal welfare and how to assess it scientifically based on the three components of animal welfare. A review of the existing literature then described animal welfare considerations for surplus dairy calves and included: 1) an overview of the surplus dairy calf industry, 2) neonatal calf care practices, and 3) calf welfare challenges during marketing and transportation. Gaps in the scientific literature with regard to the management of surplus dairy calves were identified throughout the chapters of this thesis, and the goal of this thesis research was to investigate calf welfare during marketing.

The study presented in Chapter 3 described the condition of surplus dairy calves on arrival at livestock dealers in Ohio. The specific objectives of this study where to: 1) estimate the prevalence of FTPI and poor health outcomes in surplus dairy calves on arrival at livestock dealers, and 2) identify potential risks (e.g., sale body weight, sex, source) to calf health. One of the main findings of this study was approximately one out of every five surplus calves had FTPI, with 40% having suboptimal TPI. This estimate is more than double the most recent estimate of FTPI in heifer calves (12.1%). Additionally, male calves were more likely to have signs of navel inflammation and eye discharge, which suggests discrepant care practices on the dairy farm of birth (as source was not associated with these outcomes).

One strategy to improve these outcomes for surplus dairy calves is to simply discourage discrepant neonatal care practices on the dairy farm of birth for male and female calves. It is acknowledged that modifications to current management practices likely require attitudinal and behavioral changes among dairy producers, which can be complex and multifaceted, particularly given the current economic climate. Still, similar neonatal care practices should be encouraged by industry professionals, veterinarians, etc. for male and female dairy calves. Perhaps, this could also be remedied, at least to a degree, if dairy producers were more aware of their surplus calves' destination. Generally, direct relationships between dairy and veal and dairy beef producers are nonexistent, yet their operations largely depend on one another. Future research is warranted to understand the motivations and interests of involved stakeholders, which can be achieved through application of participatory methodologies, such as deliberative democracies to allow consultative, deliberative communication between parties (reviewed by Bolton and von Keyserlingk, 2021). Moreover, while inclusion of experts is critical, the inclusion of non-experts (i.e., the public) is equally important to avoid the perpetuation of practices that remain in conflict with societal values for animal welfare.

Further, to improve surplus dairy calf welfare during marketing, calf fitness should be thoroughly assessed on the dairy farm of birth. Calves that are in poor health or unfit for transport should remain on the dairy farm until their condition improves. Likewise, calf fitness at live auctions or livestock dealers should also be assessed by a licensed veterinarian before calves are sold again or transported further to a slaughter establishment or calf-raising facility. Because the United States does not have a traceability system in place, future studies focused on characterizing calf movements are needed to understand the entire marketing process, beginning on the dairy farm of birth through entry in the veal or dairy beef production chain. Particular changes in management are also needed during marketing. For example, it is not common for calves to be provided feed or water, unless they are retained at the facility overnight. Considering the high prevalence of clinical dehydration and its likely impact on affective states, such as thirst, we strongly encourage the provision of fluids for calves during marketing at live auctions or livestock dealers. Also, marketing facilities could request that dairy producers share information at the calf level, such as colostrum management, nutrition, vaccination, etc., with the facility at the point of sale. Requesting this information would improve accountability for future calf health and could then be shared with veal and dairy beef. The surplus calf production chain in the United States is disaggregated, and the availability of important resources, such as water, as well as information sharing is necessary to ensure a more consistent level of calf care during this inherently stressful period in early life.

This work suggests that the minimum requirements, particularly Freedom from pain, injury, and disease, and Freedom from thirst, hunger, and malnutrition are currently not being met. Future research within this understudied calf population is necessary to improve calf welfare throughout the surplus dairy calf production chain: on the dairy farm of birth; during marketing; throughout the production cycle; and on to a humane death. Finally, it is important to remember that, although this young calf population is often referred to as “surplus”, these are sentient animals and, ethically, they should receive a high standard of care whilst being used for food production and under the care of humans.

Bibliography

Atkinson, D. J., M. A. G. von Keyserlingk, and D. M. Weary. 2017. Benchmarking passive transfer of immunity and growth in dairy calves. J. Dairy Sci.100(5):3773-3782. https://doi.org/10.3168/jds.2016-11800.

Barnett, J. L., and P. H. Hemsworth. 1990. The validity of physiological and behavioural measures of animal welfare. Appl. Anim. Behav. Sci. 25(1):177-187. https://doi.org/10.1016/0168-1591(90)90079-S.

Becker, J., G. Schüpbach-Regula, A. Steiner, V. Perreten, D. Wüthrich, A. Hausherr, and M. Meylan. 2020. Effects of the novel concept 'outdoor veal calf' on antimicrobial use, mortality and weight gain in Switzerland. Prev. Vet. Med. 176:104907. https://doi.org/10.1016/j.prevetmed.2020.104907.

Bell, F. R., and J. Sly. 1979. The metabolic effects of sodium depletion in calves on salt appetite assessed by operant methods. Physiol. J. 295(1):431-443. https://doi.org/10.1113/jphysiol.1979.sp012978.

Bolton, S. E., and M. A. G. von Keyserlingk, Marina A G. (2021). The dispensable surplus dairy calf: Is this issue a "wicked problem" and where do we go from here? Front. Vet. Sci. 8:660934. https://doi.org/10.3389/fvets.2021.660934.

Bravo, V. M., T. G. Knowles, and C. Gallo. 2019. Factors affecting the welfare of calves in auction markets. Animals 9(6):333. https://doi.org/10.3390/ani9060333.

Broom, D. M. 1991a. Animal welfare: concepts and measurement. J. Anim. Sci. 69(10):4167-4175. https://doi.org/10.2527/1991.69104167x.

Broom, D. M. 1991b. Assessing welfare and suffering. Behavioural Processes 25(2-3):117-123. https://doi.org/10.1016/0376-6357(91)90014-Q.

Broom, D. M. 2011. A history of animal welfare science. Acta Biotheoretica 59(2):121-137. https://doi.org/10.1007/s10441-011-9123-3.

Broom, D. M. (1988). The scientific assessment of animal welfare. Appl. Anim. Behav. Sci. 20(1):5-19. https://doi.org/10.1016/0168-1591(88)90122-0.

Broom, D. M., and K. G. Johnson. 1993. Stress and animal welfare. Chapman and Hall, London, UK. https://doi.org/10.1007/978-3-030-32153-6.

CFIA (Canadian Food Inspection Agency). 2019. Canada Gazette, Part 2, Volume 153, Number 4: Regulations Amending the Health of Animals Regulations. Accessed October 18, 2022. http://www.gazette.gc.ca/rp-pr/p2/2019/2019-02-20/html/sor-dors38-eng.html.

Cockram, M. S., and J. Y. Spence. 2012). The effects of driving events on the stability and resting behaviour of cattle, young calves and pigs. Animal Welfare 21(3):403-417. https://doi.org/10.7120/09627286.21.3.403.

Costa, J. H. C., M. A. G. von Keyserlingk, and D. M. Weary. 2016. Invited review: Effects of group housing of dairy calves on behavior, cognition, performance, and health. J. Dairy Sci. 99(4):2453-2467. https://doi.org/10.3168/jds.2015-10144.

Creutzinger, K., J. Pempek, G. Habing, K. Proudfoot, S. Locke, D. Wilson, and D. Renaud. 2021. Perspectives on the management of surplus dairy calves in the United States and Canada. Front. Vet. Sci. 8:661423. https://doi.org/10.3389/fvets.2021.661453.

Dawkins, M. 1977. Do hens suffer in battery cages? Environmental preferences and welfare. Anim. Behav. 25:1034-1046. https://doi.org/10.1016/0003-3472(77)90054-9.

Dawkins, M. S. 1990. From an animal's point of view: Motivation, fitness, and animal welfare. BBS 13(1):1-9. https://doi.org/10.1017/S0140525X00077104.

De Paula Vieira, A., M. A. G. von Keyserlingk, and D. M. Weary. 2010. Effects of pair versus single housing on performance and behavior of dairy calves before and after weaning from milk. J. Dairy Sci. 93(7):3079-3085. https://doi.org/10.3168/jds.2009-2516.

Duncan, I. 2005. Science-based assessment of animal welfare: Farm animals. Rev. Sci. Tech. Off. Int. Epiz. 24:483-492.

Etim, N. N., M. E. Williams, E. I. Evans, and E. E. A. Offiong. 2013. Physiological and behavioral responses of farm animals to stress: implications to animal productivity. Am J Adv Agric Res. 1(2):53-61. https://doi.org/10.1017/S1751731117003755.

FAWC (Farm Animal Welfare Council). 2009. Five Freedoms; Farm Animal Welfare Council, the National Archives, 2012. Accessed Oct. 22, 2022. http://webarchive.nationalarchives.gov.uk/20121007104210/http:/www.fawc.org.uk/freedoms.htm.

Fischer, A. J., Y. Song, Z. He, D. M. Haines, L. L. Guan, and M. A. Steele. 2018. Effect of delaying colostrum feeding on passive transfer and intestinal bacterial colonization in neonatal male Holstein calves. J. Dairy Sci. 101(4):3099-3109. https://doi.org/10.3168/jds.2017-13397.

Fraser, D., and Matthews, L.R. 1997. Preference and motivation testing. Pages 159-173 in Animal Welfare. M. C. Appleby and B. O. Hughes, ed. CAB International, New York, NY.

Fraser, D., D. Weary, E. Pajor, and B. Milligan. 1997. A scientific conception of animal welfare that reflects ethical concerns. Pages 187-205 in Animal Welfare. M. C. Appleby and B. O. Hughes, ed. CAB International, New York, NY.

Fordyce, A. L., L. L. Timms, K. J. Stalder, and H. D. Tyler. 2018. Short communication: The effect of novel antiseptic compounds on umbilical cord healing and incidence of infection in dairy calves. J. Dairy Sci. 101(6):5444-5448. https://doi.org/10.3168/jds.2017-13181.

Garcia, J., J. Pempek, M. Hengy, A. Hinds, D. Diaz-Campos, and G. Habing. 2022. Prevalence and predictors of bacteremia in dairy calves with diarrhea. J. Dairy Sci. 105(1):807-817. https://doi.org/10.3168/jds.2020-19819.

Godden, S. 2008. Colostrum management for dairy calves. Vet. Clin. North Am. Food Anim. 24(1):19-39. https://doi.org/10.1016/j.cvfa.2007.10.005.

Godden, S. M., J. E. Lombard, and A. R. Woolums. 2019. Colostrum management for dairy calves. Vet. Clin. North Am. Food Anim. 35(3):535-556.

Grandin, T. 1997. Assessment of stress during handling and transport. J. Anim. Sci. 75(1):249-257. https://doi.org/10.2527/1997.751249x.

Grandin, T. 2020. Review of stress and animal welfare by Donald Broom and Ken G. Johnson. Animals 10(2):363. https://doi.org/10.3390/ani10020363.

Hänninen, L., H. Hepola, S. Raussi, and H. Saloniemi. 2008. Effect of colostrum feeding method and presence of dam on the sleep, rest and sucking behaviour of newborn calves. Appl. Anim. Behav. Sci. 112(3):213-222. https://doi.org/10.1016/j.applanim.2007.09.003.

Harrison, R. 1964. Animal Machines. CAB International, London, UK.

Hughes B. O. 1982. The historical and ethical background of animal welfare. Pages 1-9 in How well do our animals fare? Proc. 15th annual conference of the reading University Agricultural Club.

Kells, N. J., N. J. Beausoleil, C. B. Johnson, J. P. Chambers, C. O'Connor, J. Webster, R. Laven, and N. Cogger. 2020. Indicators of dehydration in healthy 4- to 5-day-old dairy calves deprived of feed and water for 24 hours. J. Dairy Sci. 103(2):11820-11832. https://doi.org/10.3168/jds.2020-18743.

Kirkden, R. D., and E. A. Pajor. 2006. Using preference, motivation and aversion tests to ask scientific questions about animals’ feelings. Appl. Anim. Behav. Sci. 100:29-47. https://doi.org/10.1016/j.applanim.2006.04.009.

Kovács, L., V. Jurkovich, M. Bakony, O. Szenci, P. Póti, and J. Tőzsér. 2014. Welfare implication of measuring heart rate and heart rate variability in dairy cattle: Literature review and conclusions for future research. Animal 8(2):316-330. https://doi.org/10.1017/S1751731113002140.

Lombard, J., N. Urie, F. Garry, S. Godden, J. Quigley, T. Earleywine, S. McGuirk, D. Moore, M. Branan, M. Chamorro, G. Smith, C. Shivley, D. Catherman, D. Haines, A. J. Heinrichs, R. James, J. Maas, and K. Sterner. 2020. Consensus recommendations on calf- and herd-level passive immunity in dairy calves in the United States. J. Dairy Sci. 103(8):7611-7624. https://doi.org/10.3168/jds.2019-17955.

Lund, V. 2006. Natural living—A precondition for animal welfare in organic farming. Livest. Sci. 100(2):71-83. https://doi.org/10.1016/j.livprodsci.2005.08.005.

Marcato, F., H. van den Brand, B. Kemp, and K. van Reenen. 2018. Evaluating potential biomarkers of health and performance in veal calves. Front. Vet. Sci. 5:133. https://doi.org/10.3389/fvets.2018.00133.

McGuirk, S. M. 2008. Disease management of dairy calves and heifers. Vet. Clin. North Am. Food Anim. 24(1):139-153. https://doi.org/10.1016/j.cvfa.2007.10.003.

McGuirk, S. M., and S. F. Peek. 2014. Timely diagnosis of dairy calf respiratory disease using a standardized scoring system. Anim. Health Res. Rev. 15(2):145-147. https://doi.org/10.1017/S1466252314000267.

Mee, J. F. 2008. Newborn dairy calf management. Vet. Clin. North Am. Food Anim. 24(1):1-17. https://doi.org/10.1016/j.cvfa.2007.10.002.

Mellor, D. J., and L. Murray. 1989. Effects of tail docking and castration on behaviour and plasma cortisol concentrations in young lambs. Research in Veterinary Science 46(3):387-391. https://doi.org/10.1016/S0034-5288(18)31185-8.

Mellor, D. J. 2016. Moving beyond the “Five Freedoms” by Updating the “Five Provisions” and Introducing Aligned “Animal Welfare Aims”. Animals 6(10). https://doi.org/10.3390/ani6100059.

Pempek, J., D. Trearchis, M. Masterson, G. Habing, and K. Proudfoot. 2017. Veal calf health on the day of arrival at growers in Ohio. J. Anim. Sci. 95(9):3863-3872. https://doi.org/10.2527/jas2017.1642.

Pempek, J. A., L. R. Watkins, C. E. Bruner, and G. G. Habing. 2019. A multisite, randomized field trial to evaluate the influence of lactoferrin on the morbidity and mortality of dairy calves with diarrhea. J. Dairy Sci. 102(10):9259-9267. https://doi.org/10.3168/jds.2019-16476.

Pfeiffer, D. 2010. Quantifying disease occurrence. Pages 19-28 in Veterinary Epidemiology: An Introduction. John Wiley and Sons, Oxford, UK.

Renaud, D. L., T. F. Duffield, S. J. LeBlanc, D. F. Kelton, and D. B. Haley. 2017. Calf management risk factors on dairy farms associated with male calf mortality on veal farms. J. Dairy Sci. 101(2):1785-1794. https://doi.org/10.3168/jds.2017-13578.

Renaud, D. L., T. F. Duffield, S. J. LeBlanc, S. Ferguson, D. B. Haley, and D. F. Kelton. 2018. Risk factors associated with mortality at a milk-fed veal calf facility: A prospective cohort study. J. Dairy Sci. 101(3):2659-2668. https://doi.org/10.3168/jds.2017-13581.

Renaud, D. L., M. W. Overton, D. F. Kelton, S. J. LeBlanc, K. C. Dhuyvetter, and T. F. Duffield. 2018. Effect of health status evaluated at arrival on growth in milk-fed veal calves: A prospective single cohort study. J. Dairy Sci. 101(11):10383-10390. https://doi.org/10.3168/jds.2018-14960.

Roadknight, N., N. Courtman, P. Mansell, E. Jongman, S. Clarke-Errey, and A. Fisher. 2020. Blood collection from dairy calves at exsanguination post-slaughter yields similar biochemical and packed cell volume measurements compared with in vivo collection during lairage. Res. Vet. Sci. 130:41-47. https://doi.org/10.1016/j.rvsc.2020.02.013.

Roadknight, N. W., N. F. Courtman, P. D. Mansell, E. C. Jongman, Z. A. Loh, and A. D. Fisher. 2021. Biochemistry and hematology reference intervals for neonatal dairy calves aged 5-12 days. Vet. Clin. Pathol. 50(2):278-286. https://doi.org/10.1111/vcp.12955.

Roadknight, N., P. Mansell, E. Jongman, N. Courtman, and A. Fisher. 2021. Invited review: The welfare of young calves transported by road. J. Dairy Sci. 104(6):6343-6357. https://doi.org/10.3168/jds.2020-19346.

Roadknight, N., P. Mansell, E. Jongman, N. Courtman, D. McGill, G. Hepworth, and A. Fisher. 2021. Blood parameters of young calves at abattoirs are related to distance transported and farm of origin. J. Dairy Sci. 104(8):9164-9172. https://doi.org/10.3168/jds.2020-19729.

Robinson, A. L., L. L. Timms, K, J. Stalder, and H. D. Tyler. 2015. Short communication: The effect of 4 antiseptic compounds on umbilical cord healing and infection rates in the first 24 hours in dairy calves from a commercial herd. J. Dairy Sci. 98(8):5726-5728. https://doi.org/10.3168/jds.2014-9235.

Roccaro, M., M. Bolcato, N. T. Masebo, A. Gentile, and A. Peli. 2022. Navel healing and calf fitness for transport. Animals 12(3):358. https://doi.org/10.3390/ani12030358.

Sanchez M. M., K. M. McCormack, and B. R. Howell. 2015. Social buffering of stress responses in nonhuman primates: Maternal regulation of the development of emotional regulatory brain circuits. Soc Neurosci. 10(5):512-526. https://doi.org/10.1080/17470919.2015.1087426.

Shivley, C. B., J. Lombard, N. J. Urie, D. M. Haines, R. Sargent, C. A. Kopral, T. J. Earleywine, J. D. Olson, and F. B. Garry. 2018. Preweaned heifer management on US dairy operations: Part II. Factors associated with colostrum quality and passive transfer status of dairy heifer calves. J. Dairy Sci. 101(10):9185-9198. https://doi.org/10.3168/jds.2017-14008.

Shivley, C. B., J. E. Lombard, N. J. Urie, D. M. Weary, and M. A. G. von Keyserlingk, 2019. Management of preweaned bull calves on dairy operations in the United States. J. Dairy Sci. 102(5):4489-4497. https://doi.org/10.3168/jds.2018-15100.

Stafford, K. J., D. J. Mellor, S. E. Todd, N. G. Gregory, R. A. Bruce, and R. N. Ward. 2001. The physical state and plasma biochemical profile of young calves on arrival at a slaughter plant. NZVJ 49(4):142-149. https://doi.org/10.1080/00480169.2001.36222.

Stewart, M., H. M. Shepherd, J. R. Webster, J. R. Waas, L. M. McLeay, and K. E. Schütz. 2013. Effect of previous handling experiences on responses of dairy calves to routine husbandry procedures. Animal 7: 828–833. https://doi.org/10.1017/S175173111200225X.

Stewart, M., K. J. Stafford, S. K. Dowling, A. L. Schaefer, and J. R. Webster. 2008. Eye temperature and heart rate variability of calves disbudded with or without local anesthetic. Physiol. Behav.93:789–797. https://doi.org/10.1016/j.physbeh.2007.11.044.

Studds, M. J., L. L. Deikun, D. E. Sorter, J. A. Pempek, and K. L. Proudfoot. 2018. Short communication: The effect of diarrhea and navel inflammation on the lying behavior of veal calves. J. Dairy Sci. 101(12):11251-11255. https://doi.org/10.3168/jds.2018-15003.

Stull, C., and J. Reynolds. 2008. Calf welfare. Vet. Clin. North Am. Food Anim. 24(1):191-203. https://doi.org/10.1016/j.cvfa.2007.12.001.

Sylvester, S., K. Stafford, D. Mellor, R. Bruce, and R. Ward. 1998. Acute cortisol responses of calves to four methods of dehorning by amputation. Aust. Vet. J. 76(2):123-126. https://doi.org/10.1111/j.1751-0813.1998.tb14544.x.

Travain, T., and P. Valsecchi. 2021. Infrared thermography in the study of animals' emotional responses: A critical review. Animals 11(9):2510. https://doi.org.10.3390/ani11092510.

Trefz, F. M., I. Lorenz, A. Lorch, and P.D. Constable. 2017. Clinical signs, profound acidemia, hypoglycemia, and hypernatremia are predictive of mortality in 1,400 critically ill neonatal calves with diarrhea. PLoS One 12:e0182938. https://doi.org/10.1371/journal.pone.018293828817693.

Tucker, C. B., D. M. Weary, M. A. G. von Keyserlingk, and K. A. Beauchemin. 2009. Cow comfort in tie-stalls: Increased depth of shavings or straw bedding increases lying time. J. Dairy Sci. 92(6):2684-2690. https://doi.org/10.3168/jds.2008-1926.

United States Code. 1994. Title 49. Transportation animals. Accessed Oct. 18, 2022. https://www.animallaw.info/statute/us-food-animal-twenty-eight-hour-law.

USDA-FSIS (U.S. Department of Agriculture Food Safety and Inspection Service). 2020. FY 2020 NRP: Estimated amount of domestically produced meat, poultry, and egg products. Accessed Oct. 18, 2022. https://www.fsis.usda.gov/sites/default/files/media_file/2020-07/2020-nrp_appendix_III.pdf.

USDA. 2020. Milk production.Accessed Oct. 24, 2022: https://www.nass.usda.gov/Publications/Todays_Reports/reports/mkpr0220.pdf.

von Keyserlingk, M. A. G., A. Amorim Cestari, B. Franks, J. A. Fregonesi, and D. M. Weary. 2017. Dairy cows value access to pasture as highly as fresh feed. Sci. Rep. 7(1):1-4. https://doi.org/10.1038/srep44953.

VQA (Veal Quality Assurance). 2018. Veal Quality Assurance Certification Resource Manual. Accessed Oct. 24, 2022. https://www.veal.org/wp-content/uploads/2020/11/VQA_Manual_2018_FINAL.pdf.

Webster, A. J. F. 2001. Farm animal welfare: The Five Freedoms and the free market. Vet. J. 161(3):229-237. https://doi.org/10.1053/tvjl.2000.0563.

Webster, A. J. F., C. Saville, B. M. Church, A. Gnanasakthy, and R. Moss. 1985. Some effects of different rearing systems on health, cleanliness and injury in calves. Brit. Vet. J. 141:472-483. https://doi.org/10.1016/0007-1935(85)90042-9.

Wilson, L. L., J. L. Smith, D. L. Smith, D. L. Swanson, T. R. Drake, D. R. Wolfgang, and E. F. Wheeler. 2000. Characteristics of veal calves upon arrival, at 28 and 84 days, and at end of the production cycle. J. Dairy Sci. 83(4):843. https://doi.org/10.3168/jds.s0022-0302(00)74948-4.

Wilson, D. J., A. Justice-Allen, G. Goodell, T. J. Baldwin, R. T. Skirpstunas, and K. B. Cavender. 2011. Risk of Mycoplasma bovis transmission from contaminated sand bedding to naive dairy calves. J. Dairy Sci. 94(3):1318-1324. https://doi.org/10.3168/jds.2010-3692.

Wilson, D. J., D. Canning, T. Giacomazzi, K. Keels, R. Lothrop, D. L. Renaud, N. Sillett, D. Taylor, H. Van Huigenbos, B. Wynands, D. Zuest, and D. Fraser. 2020. Hot topic: Health and welfare challenges in the marketing of male dairy calves—Findings and consensus of an expert consultation. J. Dairy Sci. 103(12):11628-11635. https://doi.org/10.3168/jds.2020-18438.

Wilson D. J., J. Stojkov, D. L. Renaud, and D. Fraser. 2020. Risk factors for poor health outcomes for male dairy calves undergoing transportation in western Canada. Can. Vet. J. 61(12):1265-1272. PMCID: PMC7659877.

Wilson, D. J., J. Stojkov, D. L. Renaud, and D. Fraser. 2020. Short communication: Condition of male dairy calves at auction markets. J. Dairy Sci. 103(9), 8530-8534. https://doi.org/10.3168/jds.2019-17860.

Wilson, D. J., J. A. Pempek, S. M. Roche, K. C. Creutzinger, S. Locke, G. Habing, K. L. Proudfoot, K. A. George, D. L. Renaud. 2021. A focus group study of Ontario dairy producer perspectives on neonatal care of male and female calves. J. Dairy Sci. 104(5):6080-6095. https://doi.org/10.3168/jds.2020-19507.

Winder, C. B., D. F. Kelton, and T. F. Duffield. 2016. Mortality risk factors for calves entering a multi-location white veal farm in Ontario, Canada. J. Dairy Sci. 99(12):10174-10181. https://doi.org/10.3168/jds.2016-11345.

WOAH (World Organization for Animal Health). 2022. Animal welfare. Accessed Oct. 19, 2022. https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-welfare/.

Worth, G. M., K. E. Schütz, M. Stewart, V. M. Cave, M. Foster, and M. A. Sutherland. 2015. Dairy calves' preference for rearing substrate. Appl. Anim. Behav. Sci. 168:1-9. https://doi.org/10.1016/j.applanim.2015.04.003.