Ministry for Primary Industries
Manatū Ahu Matua

Bobby Calf Welfare Across the Supply Chain - Final Report for Year 1

MPI Discussion Technical Paper No: 2018/44.

Prepared for the Ministry for Primary Industries
by Alana Boulton, Nikki Kells, Ngaio Beausoleil, Naomi Cogger, Craig Johnson,
Anna Palmer, Richard Laven of Massey University and
Cheryl O'Connor, Jim Webster of AgResearch.

ISBN No: 978-1-77665-931-9 (o)
ISSN No: 2253-3923 (o)

July 2018

New Zealand Government

Disclaimer

While every effort has been made to ensure the information in this publication is accurate, the Ministry for Primary Industries does not accept any responsibility or liability for error of fact, omission, interpretation or opinion that may be present, nor for the consequences of any decisions based on this information.

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries website at
http://www.mpi.govt.nz/news-and-resources/publications/

Scientific Interpretative Summary

This SIS is prepared by MPI to provide context to the following report.

Bobby Calf Welfare Across the Supply Chain - Final Report for Year 1

This report describes research to identify reasons for mortality and morbidity in dairy calves for slaughter (bobby calves), and to identify new welfare indicators. Results are based on observations of calves, and information from questionnaires given to farmers, transport operators and slaughter plant personnel about on-farm management, transport and treatment at the processing plant. The research showed that the stage in the calving season, transport duration and slaughter schedule all affected calf mortality rates, and the research identified underlying animal health issues that can be improved through on-farm practices. The results will be used for initiatives to further improve calf welfare.

Final Report for Year 1

Bobby Calf Welfare Across the Supply Chain

Agreement No. 17556

Report prepared by

Alana Boulton, Nikki Kells, Ngaio Beausoleil, Naomi Cogger, Craig Johnson, Anna Palmer, Cheryl O'Connor, Jim Webster, Richard Laven

Final Report Submitted to New Zealand Ministry for Primary Industries
April 16 2018

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Table of Contents

List of Figures

List of Tables

Executive summary

Bobby calves are those intended for processing within approximately the first week of life for human consumption or pet food. In recent years, significant effort has gone into reducing the number of bobby calves that die or are condemned during transport or in lairage prior to slaughter in New Zealand. While mortality is extremely low (0.12% in 2016) this still represents approximately 2500 calves dying before slaughter per year, and this figure may be reduced further by understanding and addressing the risk factors in each stage of the supply chain: on-farm, during transport and in lairage at the processing plant. In addition, mortality is a crude indicator of animal welfare status and there is a need for validated indicators of calf health and welfare status to better understand the experiences of those calves that survive to the point of slaughter.

The objectives of the first year of this research programme were to investigate the risk factors for calf mortality across the supply chain and to determine the prevalence of other potential indicators of calf welfare in lairage at the processing plant. The first objective was achieved through a systematic review of the literature on risk factors for calf morbidity and mortality and by conducting a case control study, with mortality (death/condemnation) as the selected outcome. A case control design was the most appropriate approach to exploring risk factors because of the very low prevalence of calf mortality.

In the 2016 season, calves that died or were condemned before the point of slaughter (cases) and control calves that were deemed ‘acceptable’ were selected from 29 processing plants in six regions of New Zealand. Information about the on-farm, transport and processing plant management of these selected calves was gathered using retrospective questionnaires of farmers, transport operators and plant personnel. Thirty-eight case calves and 156 control calves from 194 farms were included in the analyses. Multivariate analysis of potential risk factors, collected via the questionnaires, revealed three significant factors that increased the risk of calf mortality: time in the farm of origin’s calving season, duration of travel and the processing plant’s slaughter schedule. The risk of mortality was increased when calves were collected later in the farm of origin’s calving season, transported for longer, or processed at premises with a next day slaughter schedule. Importantly, for travel duration, no threshold for increased mortality was apparent, meaning that any increase in journey time increased the risk, i.e. the shorter the journey, the lower the risk. When data from all case calves (n=38) were analysed, risk of mortality was approximately four times greater when the plant had a next day slaughter schedule. However, when cases were limited to those that died or were condemned in lairage (n=18), excluding those that were dead or condemned on arrival at the plant, the effect of slaughter schedule on mortality risk was no longer significant. As such, further research is required to determine the impact of slaughter schedule on calf mortality.

Post-mortem examination by MPI Verification Services veterinarians suggested that most case calves (died or condemned) had diarrhoea (84%) and/or enteritis (21%), and the most common reasons for condemnation were cited as weakness, recumbency, thin body condition and/or dehydration.

To achieve the second objective, a systematic review of the literature on potential welfare indicators in calves was carried out, followed by an observational study of calves in lairage at 13 different New Zealand processing plants. This study revealed seven potential indicators of calf welfare that were observed in more than 20% of calves. Dehydration, defined as a return time of ≥2 seconds using the skin tent test, was highly prevalent in individually assessed calves (63%), as were faecal soiling (44%), ocular (23%) and nasal discharge (41%), increased respiratory rate (24%), lying (38%) and oral behaviours (28%).

Taken together, the high prevalence of dehydration and faecal soiling observed in individual calves in lairage, the common citation of weakness, recumbency and dehydration as reasons for condemnation and the predominance of diarrhoea and enteritis in the post-mortem examination of case calves, suggest that dehydration associated, at least in part, with scouring is a significant risk factor for bobby calf welfare compromise and death. Thus, future research should consider the ways in which time in a farm's calving season, travel duration and next day processing impact on these factors, with the aim of identifying calves at increased risk of death, or poor welfare, earlier in the supply chain.

General introduction

Brief background to the research

Recently, there has been increased public concern over the fate and treatment of surplus or 'bobby' calves within the New Zealand dairy industry. A bobby calf is defined as an un-weaned calf that is intended for processing within approximately the first week of life for human consumption or pet food (MPI, 2015). Currently, just over 4 million dairy calves are born each year between July and September in New Zealand (Statistics NZ, 2016). Approximately one quarter of these will be kept as replacements (Hickson et al*.,* 2015), with the remainder either sold to be raised as beef cattle, killed on farm, or sold as bobby calves and sent to slaughter (Wesselink, 1998; Stafford et al., 2001; Mellor, 2011). Thus, each year in New Zealand approximately 2.2 million bobby calves are transported to slaughter, between four and seven days of age (MPI, 2017). Welfare compromise in the bobby calf industry may occur on the farm, during transport, during lairage or during slaughter. Bobby calves are at particular risk of welfare compromise due to the very young age at which they are removed from their dam, transported, and held off feed prior to slaughter (Wesselink, 1998; Fisher et al*.,* 2009).

Currently, the only routinely collected data relating to bobby calf welfare in NZ is mortality rate (i.e. death or condemnation and euthanased; MPI, 2017), along with presumed cause of death, based on post-mortem examination, in calves that die or are condemned prior to slaughter (MPI, 2015). In the 2015 season, bobby calf mortality before the point of slaughter was 0.25%, which equates to approximately 5500 calves (MPI, 2017). Since then, this number has been reduced (0.12% in 2016) by various actions undertaken by a range of parties involved in the dairy industry. While the mortality rate is extremely low, it may be possible to reduce it further by understanding and addressing the underlying risk factors in each stage of the supply chain: on-farm, during transport and in lairage at the processing plant. While mortality is likely to be an objective indicator of animal welfare in this context, its use alone is insufficient because death reflects the fact that welfare compromise was not recognised and/or appropriate steps were not taken to intervene before death. In addition, calves may survive to the point of slaughter with poor welfare status. Thus, mortality is a crude indicator of animal welfare status and there is a need for validated indicators of calf health and welfare status to better understand the experiences of those calves that survive to the point of slaughter.

Problem statement

Factors associated with the rearing, management, handling, transport and lairage of bobby calves have the potential to impact on the health and welfare of the animal, which in turn influences the mortality rate. Many studies have identified risk factors for on-farm morbidity and mortality in calves, with fewer studies focussing on the effects of transport and lairage. No studies have been found that identify risk factors for mortality in young calves across the entire supply chain. There is also a lack of data on the prevalence of indicators of poor health and welfare for bobby calves at the processing plant in New Zealand.

The aim of this research was to identify causes of, and contributing factors to, calf morbidity and mortality across the New Zealand dairy supply chain and to identify practical welfare indicators for dairy calves on farm and in lairage.

References

Fisher, A. D., Colditz, I. G., & Lee, C. F. (2009). The influence of land transport on animal welfare in extensive farming systems. Journal of Veterinary Behaviour: Clinical Applications and Research, 4 (4), 157-162.

Hickson, R. E., Zhang, I. L., & McNaughton, L. R. (2015). Brief communication: Birth weight of calves born to dairy cows in New Zealand. Proceedings of the New Zealand Society of Animal Production (75), 257-259.

Mellor, D. J. (2011). Production Animals: Ethical and Welfare Issues Raised by Production-focused Management of Newborn Livestock. In U. F. Welfare, *Veterinary & Animal Ethics: Proceedings of the First International Conference on Veterinary and Animal Ethics* (pp. 174-187). Blackwell Publishing Ltd.

MPI (Ministry for Primary Industries). 2015. MPI VS Animal Welfare Procedure for Bobby Calves.

MPI (Ministry for Primary Industries). 2017. Mortality rates in bobby calves 2008 to 2016. http://www.mpi.govt.nz/law-and-policy/legal-overviews/animal-welfare/animal-welfare-regulations/caring-for-bobby-calves/ [accessed April 2017]

Stafford, K.J., Mellor, D,J., Todd, S.E., Gregory, N.G., Bruce, R.A. and Ward, R.N., 2001. The physical state and plasma biochemical profile of young calves on arrival at a slaughter plant. New Zealand Veterinary Journal. 49, 142-149.

Statistics NZ. 2016. Agricultural production statistics: June 2015. Retrieved from: http://archive.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/AgriculturalProduction_final_HOTPJun15final.aspx

Wesselink, E. (1998). Aspects of the survival and welfare of neonatal calves. Palmerston North, New Zealand: Massey University.

Research objectives

The objectives of the research in year one were to:

1. Review the literature to identify factors potentially contributing to dairy calf mortality across the New Zealand supply chain (i.e. on farm, during transport and in lairage) and to identify potential indicators of poor calf welfare.

2. Identify, through questionnaires of suppliers, transporters and processors and through direct observation of calves, the causes of, and contributing factors to, calf morbidity and mortality across the supply chain to identify key areas of concern.

3. Produce a peer-reviewed report on year one activity, to a standard appropriate for publication in a scientific journal, and deliver a presentation at a forum agreed between the research provider and MPI.

Research objectives to be met in year two are:

4. Identification of practical welfare indicators for dairy calves for use on farm and at lairage, as an alternative to mortality rates. These indicators must be both scientifically rigorous and have practical utility for use within the industry.

5. Produce a peer-reviewed report of year two activity, to a standard appropriate for publication in a scientific journal, and deliver a presentation at a forum agreed between the research provider and MPI.

Chapter 1: Identifying risk factors for calf mortality across the New Zealand dairy supply chain

Introduction

Surplus or unwanted dairy calves, often referred to as ‘bobby calves’, are considered a by-product of the dairy industry. However, death or culling of bobby calves prior to processing represents both a welfare concern and an opportunity cost to the farm industry, as these animals could be reared as fattening cattle or sold for processing as veal and other products. In addition, animals experiencing injury, disease or various kinds of physiological dysfunction or significant homeostatic imbalance (e.g. dehydrated, malnourished, thermally stressed) are likely to have compromised welfare and be at higher risk of mortality before processing. Thus, there is a need to understand the risk factors for both mortality and morbidity in bobby calves.

In practice, mortality is the most common metric used to quantifying animal welfare, probably due to the ease of determination and lack of subjectivity (Ortiz-Pelaez et al., 2008). In contrast, morbidity, which is considered to be “any departure from a state, subjective or objective, of physiological or psychological well-being” (Porta, 2008), is often more difficult to determine, particularly when disease is subclinical. While morbidity is usually associated with the state of being diseased or sick, other factors such as malnutrition, physiological or psychological stress should be considered as departures from an animal’s state of well-being, although these are more difficult to determine and measure easily outside of experimental or behavioural studies.

In neonatal calves (up to 28 days old), mortality and morbidity are the result of multiple factors, both innate and external. Bobby calves, normally transported from the farm to the slaughter plant between 4 and 7 days of age, are subject to external factors on farm, during transport and in lairage.

The management of young calves in the first three weeks of life is critical for their health and longevity (Waltner-Toews et al., 1986; Bach, 2011; de Passillé et al., 2016). In North American and Europe, key early rearing decisions such as colostrum management, navel treatment, plane of nutrition, disease control and housing have been shown to impact on the health of young calves (Brickell et al., 2009; Gulliksen et al., 2009; Khan et al., 2011). As New Zealand is primarily a pasture-based dairy system with calves being reared at grass from an early age, management practices and thus potential risk factors for mortality and morbidity will differ from those common in other countries.

While there are longer-term financial incentives for farmers to provide the best possible rearing environment and management for their replacement heifers, there may be less incentive to do so for bobby calves. In Canada, male calves' surplus to the dairy herd are often subject to different rearing practices than replacement calves (Renaud et al., 2017). However, whether New Zealand farmers manage replacements and bobbies differently is currently unknown.

Key research activities

1. Conduct a systematic review of the literature relating to risk factors for morbidity and mortality in neonatal calves across the dairy supply chain. This review provided background information for developing the content of the farm, transport and processing plant questionnaires used in the case-control study.

2. Conduct a case-control study to identify risk factors for bobby calf mortality across the dairy supply chain.

3. A systematic review of the published literature relating to dairy farmers' consideration of animal welfare in decision-making regarding management of calves was also undertaken (Appendix 1).

1.1 Systematic review of the published literature on dairy calf mortality and morbidity

Several reviews of on-farm risk factors for mortality and morbidity in neonatal and young calves (aged up to 90 days) have been published (Torres-Medina et al. 1985; Bruning-Fann and Kaneene, 1992; Kasari, et al. 1994; Smith, 2009; Stanton et al., 2009; Phiri et al, 2010; Murray and Leslie, 2013; Meganck et al., 2014; Roland et al., 2016). However, only one review of these risk factors for neonatal calves during transport was found (Knowles, 1995), with none for risk factors associated with lairage at slaughter plants identified. The aim of this systematic review was to examine the published literature on risk factors for mortality and morbidity in neonatal calves (up to 28 days old) across the dairy supply chain.

Materials and Methods

Three systematic searches of the published scientific literature were performed using CAB Abstracts, PubMed, Web of Science and Scopus electronic databases with no starting date up until May 2016 and limited to articles written in English. The key words selected to identify literature of interest were “mortality”, “morbidity” and “survival” associated with the following: “dairy calf” OR “dairy calves” AND “bobby” OR “young” OR “heifer*” OR “pre-weaned” OR “preweaned” OR “unweaned” OR “neonatal”. To identify literature specific to livestock transport, “transport” was added as an additional search parameter. Similarly, to identify literature particular to lairage, “lairage” OR “slaughter” OR “abattoir” OR “meat processing” were added to the search.

All titles and abstracts were imported into the reference management software package EndNote where a search and removal of duplicate references were made. All abstracts were then read for relevance and included if reference was made to any or all key search terms. Full texts of the relevant articles were sourced using both printed and online resources, which included library catalogues, Google search and personal requests of authors for copies of papers via ResearchGate. Articles where full text could not be sourced were excluded.

All remaining articles were read and discarded if the literature did not refer specifically to the neonatal period. Neonatal calves were classified as those up to 28 days of age. This was essential for articles that examined calves up to 90 days of age or up to weaning but did not differentiate different age periods within this time. This is important as bobby calves are most commonly aged between 4 and 7 days when transported from the farm to the slaughter plant. Articles were also discarded if specific risk factors were not identified. Risk factors were defined as variables that had a statistically significant association with the outcome of interest (i.e. diarrhoea, mortality, etc.). References in the relevant articles were subsequently examined to identify any additional articles that were missed in the electronic database searches and these were subjected to the same inclusion criteria.

Results

A total of 494 articles were identified from the initial electronic database searches. After reading abstracts for relevance, 173 articles were retained. Full articles were then read and a further 99 discarded, leaving 74 relevant papers for consideration in the review. A further 25 articles were identified through reference checks resulting in a total of 99 articles. The articles were then separated into risk factors associated with calf management and rearing on the farm, during transport and at the slaughter plant prior to processing.

Risk factors on farm

A total of 23 and 24 risk factors for mortality and morbidity were identified, respectively (Appendix 2, Tables 2.1 and 2.2). Disease and age of the calf were the most commonly cited risk factors for both mortality (cited in 13 and 11 studies, respectively) and morbidity (each cited in 11 studies) in neonatal calves on farm. For mortality, calving difficulty (dystocia), sex of the calf, failure of passive transfer and season (weather) were further important risk factors (cited by 8, 7, 6 and 6 studies, respectively). For morbidity, frequently cited risk factors were plane of nutrition (7 studies), failure of passive transfer (7) and colostrum management (quality, source, quantity or timing; 13 studies in total).

Risk factors during transport

Five risk factors for mortality were identified for neonatal calves during transport including duration of travel, age of calf and calving season/weather (Appendix 2, Table 2.3). Nineteen risk factors were identified for morbidity, with dehydration and loss of bodyweight (4 studies each), lying time (5 studies) and increased serum creatinine kinase concentration (4 studies) being the most frequently cited (Appendix 2, Table 2.4).

Risk factors during lairage at processing plant

Few studies were found that examined risk factors for mortality and/or morbidity of neonatal calves in lairage at slaughter plants prior to slaughter. For mortality, 6 risk factors were cited in a single study: 'disease', mild diarrhoea, emaciation, milk in the rumen, lack of curd in the abomasum and non-fatal trauma (Appendix 2, Table 2.5). For morbidity, 4 factors were cited in two studies, reflecting loss of body weight and changes in plasma metabolites (Appendix 2, Table 2.6).

Discussion

This structured review identified 31 and 42 different risk factors for mortality and morbidity, respectively, in neonatal calves across the dairy supply chain. Risk factors were categorised into environmental, management, calf and miscellaneous factors. Environmental factors apply to the calf's surrounding such as calving area, type of housing, stocking density and weather (season). Management factors include the rearing decisions made by the farmer on colostrum management, plane of nutrition, choice of calf rearer and health care. Calf factors include indicators of metabolic status, such as plasma cortisol, glucose and creatine kinase concentrations as well as calf age, birthweight, live weight and sex. Disease was included in calf factors; however, it should be noted that common calfhood diseases are usually multifactorial and not a consequence of one single risk factor.

Disease and calf age were frequently identified risk factors for both mortality and morbidity on farm. Calf age was also cited as a risk factor for mortality during transport, while disease was cited in the single paper found exploring risk factors for mortality in lairage. Neonatal calves are particularly susceptible to infectious gastrointestinal and respiratory disease. During the neonatal period the calf undergoes critical changes in its digestive system and the waning of maternal antibodies and increased susceptibility to major calf hood diseases such as enteritis (scours) and bovine respiratory disease (pneumonia).

The majority of cases of scouring occur in the first three weeks of life (Waltner-Toews et al., 1986b; Sivula et al., 1996; Virtala et al., 1996; Svennson et al., 20063; Svennson et al., 2006; Trotz-Williams et al., 2007). Calf diarrhoea can have both an infectious and non-infectious aetiology, and co-infection is common in scouring calves (Hall et al., 1988; de la Fuente et al., 1998; Al Mawly et al., 2015). Pathogens responsible for enteric disease include *Escherichia coli*, rotavirus, cryptosporidiosis, salmonella, coccidiosis, coronavirus, bovine diarrhoea virus and *Clostridium perfringens*. Severity of infection is thought to be influenced by management, poorly ventilated housing, hygiene (Castro-Hermida et al., 2002), the immune status of the animal (which itself is a product of passive transfer of maternal antibodies) (Razzaque et al., 2009c; Maganck et al., 2014) and climate (Fallon and Harte, 1983; Gulliksen *et al*., 2009a). Other calf-level risk factors for diarrhoea that have been identified are breed (Svennson et al., 2003; Al Mawly et al., 2015; Delafosse et al., 2015), season (Svennson et al., 2003; Trotz-Williams et al., 2007), method of colostrum feeding and parity of dam providing colostrum (Svennson et al., 2003).

Calf diarrhoea can also have a non-infectious origin. Plane of nutrition has been associated with increased faecal soiling and decreased solidity of faeces (Quigley et al., 2006). However, other studies have found no differences in faecal consistency or volume with increased milk feeding (Jasper and Weary, 2002). The current literature review revealed plane of nutrition as a commonly cited risk factor for morbidity on farm, as were related factors, colostrum management and failure of passive transfer.

Failure of passive transfer (FPT) occurs when IgG concentration in calf serum is less than 10 mg/ml (50g IgG/L) (Weaver et al., 2000; Godden, 2008; Elizondo-Salaza and Heinrichs, 2009) and has previously been identified as a risk factor for calfhood disease and death (Simensen, 1982; Razzaque et al., 2009a,c; Windeyer et al., 2012; Aly et al., 2013; Priestley et al., 2013; Uetake, 2013; Windeyer et al., 2014 Raboisson et al., 2016). The likelihood of FPT is influenced by the quality of the colostrum the calf receives, which is, in turn, determined by such management factors as storage (Stewart et al., 2005), hygiene, bacterial contamination (Stewart et al., 2005; Morrill et al., 2012; Meganck et al., 2014), pasteurization (Godden et al., 2006; Elizondon-Salazar and Heinrichs, 2009; Armengol and Fraile, 2016) and parity of the dam (Gulliksen et al., 2008; Morrill et al., 2012). Source, timing and quantity of colostrum are other important risk factors for morbidity in neonatal calves. The ability of the gut to absorb IgG diminishes after 12 hours from birth. Thus, ideally, colostrum should be ingested in the first 4 hours to ensure maximum absorption (Beam et al., 2009).

With regard to longer-term plane of nutrition, conventional or restricted milk feeding, twice a day at 10% of a calf's birthweight (4-5 litres) is the most common method employed on dairy farms in the USA, Canada and South Korea (Davis and Drackley, 1998; Appleby et al. 2001; Jasper and Weary, 2002; Khan et al. 2011). Limit-feeding calves milk or milk replacer to encourage solid feed intake (e.g. once-daily) has been challenged in recent decades as studies have found associations with poor health, welfare and weight gain (Hammon et al., 2002; Osorio et al., 2012; de Passillé et al., 2016).

In contrast to gastrointestinal disease, respiratory disease is more common in older calves (Sivula et al., 1996; Virtala et al., 1996; Svennson et al., 2003; Windeyer et al., 2012). Common causative agents include bovine respiratory syncytial virus, parainfluenza virus, bovine coronavirus, bovine viral diarrhoea virus and bovine herpes virus 1, and respiratory disease can often leave the immune system compromised (Curtis et al., 1988; Windeyer et al., 2014). On farm risk factors considered important in the development of respiratory disease include poor ventilation in calf housing (van der Fels-Klerx) and large pen group size (Losinger and Heinrichs, A.J., 1997; Svennson et al., 2003; Svennson et al., 2006).

On-farm housing of neonatal calves should be clean and well ventilated, meeting statutory regulations on living and feed space and providing access to clean water. In New Zealand, replacement heifers are most commonly group-housed in indoor pens for a minimum of 7 days before being provided access to an outdoor space. The type of housing (Bruning-Fann, 1992; Trotz-Williams et al., 2008; Razzaque et al., 2009_a; Marcé et al., 2010; Lorenz et al., 2011), individual or group pens, group size (Quigley et al., 1994; Losinger, 1997; Weary, 2001; Svennson et al., 2003; Svennson and Liberg, 2006; Lorenz et al., 2011) and hygiene (Trotz-Williams et al., 2008; Wudu et al., 2008) have all be shown to affect the rate of disease transmission between calves. Individual housing has been associated with decreased risk for both enteric and respiratory disease (Gulliksen et al., 2009b). Transmission of pathogens is increased through exposure to older animals, contaminated environments and direct contact between calves.

Poor ventilation results in increased humidity and levels of dust and noxious gases such as ammonia. Other management and environmental factors associated with increased risk of pneumonia include; season of birth, incidence of pneumonia on the farm, navel dipping, FPT (Windeyer et al., 2014) and sharing housing with adult cattle during the first week of life (Svennson et al., 2003; Svennson et al., 2006; Gulliksen et al., 2009b). Decreased odds of respiratory disease have been associated with supervision of calving and calving in individual maternity pens (Svennson et al., 2003).

Other commonly cited risk factors for mortality on farm included dystocia and sex of calf. The reason for calf sex arising as a relatively commonly cited risk factor for mortality on farm may reflect different management of male and female calves or genuine biological differences in risk of mortality. Renaud et al. (2017) reported that in Canada, male calves surplus to the dairy herd are often subject to different rearing practices to replacement calves. A difficult or abnormal calving can have deleterious effects on the newborn calf (Lombard et al., 2007; Beam et al., 2009; Furman-Fratczak et al., 2011; Barrier et al., 2013; Murray et al., 2015; Vannucchi et al., 2015). Johanson and Berger (2003) determined a 13% increase in the probability of dystocia for every 1 kg increase in birthweight. Sex and breed of the calf have also been linked with increased likelihood of dystocia (Johanson and Berger, 2003; Heins et al., 2006). Calves experiencing a difficult birth have been shown to have an impaired thermic response to cold weather (Bellows and Lammonglia, 2000), and an increased risk of failure of passive transfer (Beam et al., 2009).

Studies of risk factors for mortality or morbidity of calves during transport or in lairage at processing plants were much less common that those exploring risks on farm. Season or weather was cited as a mortality risk factor both on farm and during transport. Calf age and travel duration also influence calf mortality during transport. Risk factors for calf morbidity after calves had left the farm appeared to relate to metabolic exhaustion and/or dehydration. This may reflect the fact that calves had not been fed for a prolonged period or alternatively reflect the measures made during these components of the supply chain.

Calves are subjected to stresses during transportation such as loading and unloading (Kent, 1986; Cave et al., 2005), long journey times (Cave et al., 2005; Večerek, et al., 2006 Uetake et al., 2011) and novel human-animal contact (Lensink et al, 2001). Transportation results in changes to biochemical, hormonal and metabolic parameters that have adverse effects on the calf (Trunkfield and Broom, 1990). Reduced lying time and positional changes have been associated with inadequate floor space allowance (Uetake et al., 2011) and are likely contributors to mechanical damage (trauma) due to trampling and prolonged periods of standing resulting in elevated creatine kinase (CK) concentrations (Stafford et al., 2001). Travel duration may also influence risk of mortality by influencing time since last feed. In support of this, changes in metabolic profiles have been shown to be more pronounced with extended journey times (Knowles et al., 1997).

On arrival at slaughter plants in New Zealand bobby calves are evaluated and monitored as they are unloaded, during lairage and prior to slaughter. Calves that are unable to walk off the transport or up to slaughter or that are identified as being in a poor state of health during lairage are condemned and euthanased. Stafford et al (2001) found that calves classified as ‘unacceptable’ (extremely weak, injured, unable to stand or walk) under the New Zealand guidelines for transporting young animals had high BHB and urea concentrations and concluded that this was probably due to inanition. In the current review, disease and indicators of metabolic exhaustion were cited as risk factors for mortality and morbidity in lairage, respectively. In one study, post mortem results showed that digestive tract disorders and omphalitis accounted for the majority of condemnations of NZ calves in the slaughter plant (Thomas and Jordaan, 2013). Secondary findings in condemned calves were emaciation, mild diarrhoea, milk in the rumen and non-fatal trauma. Blood samples taken from calves in lairage showed changes to metabolic profiles indicative of dehydration and fasting (Stafford et al., 2001). A number of papers examining the prevalence of disease indicators in condemned carcases post slaughter showed omphalophlebitis (navel ill) and enzootic pneumonia as the most common diseases present (McCausland et al., 1977; Hathaway et al., 1993; Biss et al., 1994; Biss and Hathaway, 1994).

These findings illustrate the caution required in interpreting the apparent frequency with which particular risk factors were identified in this body of literature. Risk factors can be cumulative across the supply chain, whereby pre-existing conditions or the effects of earlier management may be exacerbated by the additional stresses associated with transport and lairage. As such, factors occurring late in the chain, such as extended transport and lairage times or prolonged time since last feed, may contribute to an otherwise acceptable calf becoming marginal or unacceptable. Other caveats on interpretation include possible biases in the body of literature itself or the literature accessed for the review. For example, research written in languages other than English or that available in the grey literature (e.g. industry publications) may have revealed different risk factors for calf mortality or morbidity. Within individual studies, differences exist in the measures that can be feasibly made at each stage of the supply chain. For example, while factors such as age, birthweight, dystocia and calf management may be easily gathered from farm records to assess their contribution to mortality and morbidity, such information is much more difficult to access when calves have left the farm. Finally, it should be acknowledged that many of the articles identified in this literature search related to calf production systems outside of New Zealand and/or related to calves older than two weeks of age. Thus, caution should be exercised in applying the findings to the New Zealand bobby calf industry context.

References

Al Mawly, J., Grinberg, A., Prattley, D., Moffat, J., Marshall, J., French, N., 2015. Risk factors for neonatal calf diarrhoea and enteropathogen shedding in New Zealand dairy farms. Vet. J. 203, 155-160.

Aly, S. S., Pithua, P., Champagne, J. D., & Haines, D. M. (2013). A randomized controlled trial on preweaning morbidity, growth and mortality in Holstein heifers fed a lacteal-derived colostrum replacer or pooled maternal colostrum. BMC Vet. Res. 9, 168.

Anonymous. (2016a). Animal Welfare (Calves) Regulations 2016. Wellington, New Zealand: New Zealand Government. Retrieved from: http://www.legislation.govt.nz/all/results.aspx?search=ts_act%40bill%40regulation%40deemedreg_calves_resel_25_a&p=1

Anonymous. (2016b). Code of Welfare: Dairy Cattle. Wellington, New Zealand: New Zealand Government.

Appleby, M., Weary, D.M., Chua, B., 2001. Performance and feeding behaviour of calves on ad libitum milk from artificial teats. Appl. Anim. Behav. Sci. 74, 191-201.

Armengol, R., Fraile, L., 2016. Colostrum and milk pasteurization improve health status and decrease mortality in neonatal calves receiving appropriate colostrum ingestion. J. Dairy Sci. 99, 4718-4725.

Arnott, G., Roberts, D., Rooke, J.A., Turner, S.P., Lawrence, A.B., Rutherford, K.M.D., 2012. Board invited review: The importance of the gestation period for welfare of calves: Maternal stressors and difficult births. J. Anim. Sci. 90, 5021-5034.

Atkinson, P.J., 1992. Investigation of the effects of transport and lairage on hydration state and resting behaviour of calves for export. Vet. Rec. 130, 413-416.

Bach A. 2011. Associations between several aspects of heifer development and dairy cow survivability to second lactation. J. Dairy Sci, 94, 1052-57.

Barrier, A.C., Haskell, M.J., Birch, S., Bagnall, A., Bell, D.J., Dickinson, J., Macrae, A.I., Dwyer, C.M., 2013. The impact of dystocia on dairy calf health, welfare, performance and survival. Vet. J. 195, 86-90.

Beam, A.L., Lombard, J.E., Kopral, C.A., Garber, L.P., Winter, A.L., Hicks, J.A., Schlater, J.L., 2009. Prevalence of failure of passive transfer of immunity in newborn heifer calves and associated management practices on US dairy operations. J. Dairy Sci. 92, 3973-3980.

Bellows, R., Lammoglia, M., 2000. Effects of severity of dystocia on cold tolerance and serum concentrations of glucose and cortisol in neonatal beef calves. Theriogenology. 53, 803-813.

Biss, M.E., Hathaway, S.C., 1994. Wastage due to diseases and defects in very young calves slaughtered in New Zealand. New Zeal. Vet J. 42, 211-215.

Biss, M.E., Alley, M.R., Madie, P., Hathaway, S.C., 1994. Lesions in the carcasses and viscera of very young slaughter calves condemned at post-mortem meat inspection. New Zeal. Vet J. 42, 121-127.

Borderas, T.F., Rushen, J., von Keyserlingk, M.A.G., de Pasille, A.M., 2009. Automated measurement of changes in feeding behaviour of milk fed calves associated with illness. J. Dairy Sci. 92, 4549-4554.

Brickell, J., McGowan, M., Pfeiffer, D., Wathes, D., 2009. Mortality in Holstein-Friesian calves and replacement heifers, in relation to body weight and IGF-I concentration, on 19 farms in England. Animal. 3, 1175-1182.

Bruning-Fann, C., Kaneene, J. B., 1992. Environmental and management risk factors associated with morbidity and mortality in perinatal and pre-weaning calves: a review from an epidemiological perspective. Vet. Bull. 62, 399-413.

Castro-Hermida, J.A., González-Losada, Y.A., Ares-Mazás, E., 2002. Prevalence of and risk factors involved in the spread of neonatal bovine cryptosporidiosis in Galicia (NW Spain). Vet. Parasitol. 106, 1-10.

Cave, J.G., Callinan, A.P.L., Woonton, W.K., 2005. Mortalities in bobby calves associated with long distance transport. Aust. Vet. J. 83, 82-84.

Curtis, C.R., Erb, H.N., White, M.E., 1988. Descriptive epidemiology of calfhood morbidity and mortality in New York Holstein herds. Prev. Vet. Med. 5,293–307.

Davis, C.L., Drackley, J.K., 1998. The development, nutrition, and management of the young calf. University Press, Ames, IA.

Debnath, N., Taimur, M., Saha, A., Ersaduzaman, M., Helaluddin, M., Rahman, M., Roy, D.K., Islam, M., 1995. A retrospective study of calf losses on the central dairy cattle breeding station in Bangladesh. Prev. Vet. Med. 24, 43-53.

De La Fuente, R., Garcia, A., Ruiz-Santa-Quiteria, J. A., Luzón, M., Cid, D., García, S., Orden, J.A., Gómez-Bautista, M., 1998. Proportional morbidity rates of enteropathogens among diarrheic dairy calves in central Spain. Prev. Vet. Med. 36, 145-152.

de Pasillé, A.M., Rabeyrin, M., Rushen, J., 2016. Associations between milk intake and activity in the first days of a calf's life and later growth and health. Appl. Anim. Behav. Sci. 175, 2-7.

Delafosse, A., Chartier, C., Dupuy, M.C., Dumoulin, M., Pors, I., Paraud, C., 2015. Cryptosporidium parvum infection and associated risk factors in dairy calves in western France. Prev. Vet. Med. 118, 406-412.

Elizondo-Salazar, J., Heinrichs, A., 2009. Feeding heat-treated colostrum to neonatal dairy heifers: Effects on growth characteristics and blood parameters. J. Dairy Sci. 92, 3265-3273.

Fallon, R., Harte, F., 1983. The occurrence of diarrhoea in calves under different management systems. Ann. Rech. Vet. 14, 473-478.

Fisher, A.D., Stevens, B.H., Conley, M.J., Jongman, E.C., Lauber, M.C., Hides, S.J., Anderson, G.A., Duganzich, D.M., Mansell, P.D., 2014. The effects of direct and indirect road transport consignment in combination with feed withdrawal in young dairy calves. J. Dairy Res. 81, 297-303.

Franklin, S.T., Amaral-Phillips, D.M., Jackson, J.A., Campbell, A.A., 2003. Health and performance of Holstein calves that suckled or were hand-fed colostrum and were fed one of three physical forms of starter. J. Dairy Sci. 86, 2145-2153.

Furman-Fratczak, K., Rzasa, A., Stefaniak, T., 2011. The influence of colostral immunoglobulin concentration in heifer calves' serum on their health and growth. J. Dairy Sci. 94, 5536-5543.

Gitau, G., McDermott, J., Waltner-Toews, D., Lissemore, K., Osumo, J., Muriuki, D., 1994.

Factors influencing calf morbidity and mortality in smallholder dairy farms in Kiambu District of Kenya. Prev. Vet. Med. 21, 167-177.

Godden, S.M., McMartin, S., Feirtag, J., Stabel, J., Bey, R., Goyal, S., Metzger, L., Fetrow, J., Wells, S., Chester-Jones, H., 2006. Heat-treatment of bovine colostrum. II: Effects of heating duration on pathogen viability and immunoglobulin G. J. Dairy Sci. 89, 3476–3483.

Godden, S., 2008. Colostrum management for diary calves. Vet. Clin. Food. Anim. 24, 19-39.

Godden, S.M., Haines, D.M., Konkol, K., Peterson, J., 2009. Improving passive transfer of immunoglobulins in calves. II: Interaction between feeding method and volume of colostrum fed. J. Dairy Sci. 92, 1758–1764.

Grigor, P.N., Cockram, S.M., Steele, W.B., Le Sueur, C.J., Forsyth, R.E., Guthrie, J.A., Johnson, A.K., Sandilands, V., Reid, H.W., Sinclair, C., Brown, H.K., 2001. Effects of space allowance during transport and duration of mid-journey lairage period on the physiological, behavioural and immunological responses of young calves during and after transport. Anim. Sci. 73, 341-360.

Gulliksen, S.M., Lie, K.I., Sølverød, L., Østerås, O., 2008. Risk factors associated with colostrum quality in Norwegian dairy cows. J. Dairy Sci. 91:704–712.

Gulliksen, S.M., Lie, K.I., Løken, T., Østerås, O., 2009a. Calf mortality in Norwegian dairy herds. J. Dairy Sci. 92, 2782-2795.

Gulliksen, S.M., Jor, E., Lie, K.I., Løken, T., Akerstedt, J., Østerås, O., 2009b. Respiratory infections in Norwegian dairy calves. J. Dairy Sci. 92, 5139-5146.

Hall, G.A., Reynolds, D.J., Parsons, K.R., Bland, A.P., Morgan, J.H., 1988. Pathology of calves with diarrhoea in southern Britain. Res. Vet. Sci. 45, 240-50.

Hammon, H.M., Schiessler, G., Nussbaum, A., Blum, J.S., 2002. Feed intake patterns, growth performance, and metabolic and endocrine traits in calves fed unlimited amounts of colostrum and milk by automate, starting in the neonatal period. J. Dairy Sci. 85, 3352-3362.

Hathaway, S.C., Bullians, J.A., Johnstone, A.C., Biss, M.E., Thompson, A., 1993. A pathological and microbiological evaluation of omphalophlebitis in very young calves slaughtered in New Zealand. New Zeal. Vet. J. 41, 166-170.

Heins, B.J., Hansen, L.B., Seykora, A.J., 2006. Calving difficulty and stillbirths of pure Holstein versus crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. J. Dairy Sci. 89, 2805-2810.

Jasper, J., Weary, D.M., 2002. Effects of ad libitum milk intake on dairy calves. J. Dairy Sci. 85, 3054-3058.

Johanson, J., Berger, P., 2003. Birth weight as a predictor of calving ease and perinatal mortality in Holstein cattle. J. Dairy Sci. 86, 3745-3755.

Jongman, E.C., Butler, K.L., 2014. The effect of age, stocking density and flooring during transport on welfare of young dairy calves in Australia. Animals. 4, 184-199.

Kasari, T.R., 1994. Weakness in the newborn calf. Vet. Clin. North Am. Food Anim. Pract. 10, 167-180.

Kent, J.E., Ewbank, R., 1986. The effect of road transportation on the blood constituents and behaviour of calves. II. One to three weeks old. Br. Vet. J. 142, 131-140.

Khan, M.A., Lee, H.J., Lee, W.S., Kim, H.S., Kim, S.B. Ki, K.S., Ha, J.K., Lee, H.G. and Choi, Y.J., 2007. Pre- and postweaning performance of Holstein female calves fed milk through step-down and conventional methods. J. Dairy Sci. 90, 876-885.

Khan, M., Weary, D., Von Keyserlingk, M., 2011. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. J. Dairy Sci. 94, 1071-1081.

Knowles, T.G., 1995. A review of post transport mortality among younger calves. Vet. Rec. 137, 406-407.

Knowles, T.G., Warriss, P.D., Brown, S.N., Edwards, J.E., Watkins, P.E., Phillips, A.J., 1997. Effects on calves less than one month old of feeding or not feeding them during road transport of up to 24 hours. Vet. Rec. 140, 116-124.

Knowles, T.G., Brown, S.N., Edwards, J.E., Phillips, A.J., Warriss, P.D., 1999. Effect on young calves of a one-hour feeding stop during a 19-hour road journey. Vet. Rec. 144, 687-692.

Lance, S.E., Miller, G.Y., Hancock, D.D., Bartlett, P.C., Heider, L.E., Moeschberger, M.L., 1992. Effects of environment and management on mortality in preweaned dairy calves. J. A. Vet. Med. Assoc. 201, 1197-1202.

Lensink, B.J., Raussi, S., Voivin, X., Pyykkonen, M.,Veissier, I., 2001. Reactions of calves to handling depend on housing condition and previous experience with human. Appl. Anim. Behav. Sci. 70, 187-199.

Lombard, J.E., Garry, F.B., Tomlinson, S.M., Garber, L.P., 2007. Impacts of dystocia on health and survival of dairy calves. J. Dairy Sci. 90, 1751-1760.

Longenbach, J., Heinrichs, A., 1998. A review of the importance and physiological role of curd formation in the abomasum of young calves. Anim. Feed Sci. Tech. 73, 85-97.

Lorenz, I., Earley, B., Gilmore, J., Hogan, I., Kennedy, E., More, S.J., 2011. Calf health from birth to weaning. III. housing and management of calf pneumonia. Irish Vet. J. 64, 14.

Losinger, W.C., Heinrichs, A.J., 1997. Management practices associated with high mortality among preweaned dairy heifers. J. Dairy Res. 64, 1-11.

Mansour, A.E., Abdelgadir, A.E., El Zubeir, I.E., 2014. Major causes and risk factors associated with calf mortality in dairy farms in Khartoum State, Sudan. J. Vet. Med. Anim. Hlth. 6, 145-153.

Marcé, C., Guatteo, R., Bareille, N., Fourichon, C., 2010. Dairy calf housing systems across Europe and risk for calf infectious diseases. Animal. 4, 1588-1596

Martin, S.W., Schwabe, C.W., Franti, C.E., 1975a. Dairy calf mortality rate: the association of daily meteorological factors and calf mortality. Can. J. Comp. Med. 39, 377-388.

Martin, S.W., Schwabe, C.W., Franti, C.E., 1975b. Dairy calf mortality rate: characteristics of calf mortality rates in Tulare County, California. Am. J. Vet. Res. 36, 1099-1104.

McCausland, I.P., Austin, D.F., Dougherty, R., 1977. Stifle bruising in bobby calves. New Zeal. Vet J. 25, 71-72.

Meganck, V., Hoflack, G., Opsomer, G., 2014. Advances in prevention and therapy of neonatal dairy calf diarrhoea: A systematical review with emphasis on colostrum management and fluid therapy. Acta Vet. Scand. 56, 75.

Megersa, B., Yacob, A., Regassa, A., Abuna, F., Asmare, K., Amenu, K., 2009. Prevalence and incidence rates of calf morbidity and mortality and associated risk factors in smallholder dairy farms in Hawassa, Southern Ethiopia. Ethiop. Vet. J. 13, 59-68.

Mellado, M., Lopez, E., Veliz, F.G., De Santiago, M.A., Macias-Cruz, U., Avendaño-Reyes, L., Garcia, J.E. 2014. Factors associated with neonatal dairy calf mortality in a hot-arid environment. Livest. Sci. 159, 149-155.

Morin, D.E., McCoy, G.C., Hurley, W.L., 1997. Effects of quality, quantity, and timing of colostrum feeding and addition of a dried colostrum supplement on immunoglobulin G1 absorption in Holstein bull calves. J. Dairy Sci. 80, 747–753.

Mormede, P., Soissons, J., Bluthe, R.M., Raoult, J., Legarff, G., Levieux, D., Dantzer, R., 1982. Effect of transport on blood serum composition, disease incidence, and production traits in young calves. Influence of the journey duration. Ann. Rech. Vet. 13, 369-384.

Morrell, E.L., Moore, D.P., Odeon, A.C., Poso, M.A., Odriozola, E., Canton, G., Paolicchi, F., Malena, R., Leunda, M.R., Morsella, C., Campero, C.M., 2008. Retrospective study of bovine neonatal mortality: cases reported from INTA Balcarce, Argentina. Rev. Argent. Microbiol. 40, 151-157.

Morrill, K.M., Conrad, E., Lago, A., Campbell, J., Quigley, J.D., Tyler, H., 2012. Nationwide evaluation of quality and composition of colostrum on dairy farms in the United States. J. Dairy Sci. 95:3997–4005.

Murray, C.F., Leslie, K.E., 2013. Newborn calf vitality: Risk factors, characteristics, assessment, resulting outcomes and strategies for improvement. Vet. J. 198, 322-328.

Murray, C.F., Veira, D.M., Nadalin, A.L., Haines, D.M., Jackson, M.L., Pearl, D.L., Leslie, K.E., 2015. The effect of dystocia on physiological and behavioural characteristics related to vitality and passive transfer of immunoglobulins in newborn Holstein calves. Can. J. Vet. Res. 79, 109-119.

Olson, D., Papasian, C., Ritter, R., 1980. The effects of cold stress on neonatal calves. II. Absorption of colostral immunoglobulins. Can. J. Comparat. Med. 44, 19-23.

Ortiz-Pelaez, A., Pritchard, D.G., Pfeiffer, D.U., Jones, E., Honeyman, P., Mawdsley, J.J., 2008. Calf mortality as a welfare indicator on British cattle farms. Vet. J. 176, 177-181.

Osorio, J.S., Wallace, R.L., Tomlinson, D.J., Earleywine, T.J., Socha, M.T., Drackley, J.K., 2012. Effects of source of trace minerals and plane of nutrition on growth and health of transported neonatal dairy calves. J. Dairy Sci. 95: 5831-5844.

Pare, J., Thurmond, M.C., Gardner, I.A., Picanso, J.P., 1993. Effect of birthweight, total protein, serum IgG and packed cell volume on risk of neonatal diarrhoea in calves on two California dairies. Can. J. Vet. Res. 57, 241-246.

Patel, S., Gibbons, J., Wathes, D.C., 2014. Ensuring optimal colostrum transfer to newborn dairy calves. Cattle Pract. 22, 95-104.

Phiri, B., Benschop, J., French, N., 2010. Systematic review of causes and factors associated with morbidity and mortality on smallholder dairy farms in Eastern and Southern Africa. Prev. Vet. Med. 94, 1-8.

Porta, M (ed). 2008. A Dictionary of Epidemiology. Oxford University Press, New York.

Priestley, D., Bittar, J.H., Ibarbia, L., Risco, C.A., Galvão, K.N., 2013. Effect of feeding maternal colostrum or plasma-derived or colostrum-derived colostrum replacer on passive transfer of immunity, health, and performance of preweaning heifer calves. J. Dairy Sci. 96, 3247-3256.

Quigley, J.D., Martin, K.R., Bemis, D.A., Potgieter, L.N.D., Reinemeyer, C.R., Rohrbach, B.W., Dowlen, H.H., Lamar, K.C., 1994. Effects of housing and colostrum feed on the prevalence of selected infectious organisms in faeces of Jersey calves. J. Dairy Sci. 77, 3124-3131.

Quigley, J.D., Wolfe, T.A., Elsasser, T.H., 2006. Effects of additional milk replacer feeding on calf health, growth, and selected blood metabolites in calves. J. Dairy Sci. 89, 207-216.

Raboisson, D., Delor, F., Cahuzac, E., Gendre, C., Sans, P., Allaire, G., 2013. Perinatal, neonatal, and rearing period mortality of dairy calves and replacement heifers in France. J. Dairy Sci. 96, 2913-2924

Raboisson, D., Maigne, E., Sans, P., Allaire, G., Cahuzac, E., 2014. Factors influencing dairy calf and replacement heifer mortality in France. J. Dairy Sci. 97, 202-211.

Raboisson, D., Trillat, P., Cahuzac, C., 2016. Failure of passive immunce transfer in calves:

A meta-analysis on the consequences and assessment of the economic impact. Plos One, 11(3).

Razzaque, M.A., Mohammed, S.A., Al-Mutawa, T., Bedair, M., 2009a. Improving performance of replacement heifers in hot arid environment under intensive management. Am. J. Anim. Vet. Sci. 4, 85-91.

Razzaque, M., Abbas, S., Bedair, M., 2009b. Mortality of pre-weaned calves in Kuwait's dairy herds, its causes and impact of interventions. Internet J. Vet. Med. 5(2).

Razzaque, M.A., Al-Mutawa, T., Abbas, S., Bedair, M., 2009c. Performance of pre-weaned dairy calves under hot arid environment: Effects of immunoglobulins and age on diseases and mortality. Am. J. Appl. Sci. 6, 1885-1891.

Razzaque, M., Al-Mutawa, T., Mohammed, S., 2010. Diarrhea in pre-weaned calves: relative risk rates for morbidity and mortality in 13 commercial farms of hot arid zone. Am. J. Anim. Vet. Sci. 5, 215-220.

Renaud DL, Duffield TF, LeBlanc SJ, Haley DB, Kelton, DF. 2017. Management practices for male calves on Canadian dairy farms. J. Dairy Sci. 100, 1-10.

Roland, L., Drillich, M., Klein-Joebstl, D., Iwersen, M., 2016. Invited review: Influence of climatic conditions on the development, performance, and health of calves. J. Dairy Sci. 99, 2438-2452.

Roy, J., 1980. Factors affecting susceptibility of calves to disease. J. Dairy Sci. 63, 650-664.

Simensen, E., 1982. An epidemiological study of calf health and performance in Norwegian dairy herds: I. Mortality: Literature review, rates and characteristics. Acta Agr. Scand. 32, 411-419.

Singh, B.B., Sharma, R., Kumar, H., Banga, H.S., Aulakh, R.S., Gill, J.P.S., Sharma, J.K., 2006. Prevalence of Cryptosporidium parvum infection in Punjab (India) and its association with diarrhoea in neonatal dairy calves. Vet. Parasitol. 140, 162-165.

Sivula, N.J., Ames, T.R., Marsh, W.E., Werdin, R.E., 1996. Descriptive epidemiology of morbidity and mortality in Minnesota dairy heifer calves. Prev. Vet. Med. 27, 155-171.

Smith, G.W., 2009. Treatment of calf diarrhea: oral fluid therapy. Vet. Clin. North Am. Food

Anim. Pract. 25, 55-72.

Stafford, K.J., Mellor, D,J., Todd, S.E., Gregory, N.G., Bruce, R.A., Ward, R.N., 2001. The physical state and plasma biochemical profile of young calves on arrival at a slaughter plant. New Zeal. Vet. J. 49, 142-149.

Stanton, A., 2009. Challenges and opportunities for managing respiratory disease in dairy calves. Anim. Health Res. Rev. 10, 113-115.

Staples, G.E., Haugse, C.N., 1974. Losses in young calves after transportation. Br. Vet. J. 130, 374-378.

Stewart, S., Godden, S., Bey, R., Rapnicki, P., Fetrow, J., Farnsworth, R., Scanlon, M., Arnold, Y., Clow, L., Mueller, K., Ferrouillet, C., 2005. Preventing bacterial contamination and proliferation during the harvest, storage, and feeding of fresh bovine colostrum. J. Dairy Sci. 88, 2571-2578.

Svensson, C., Lundborg, K., Emanuelson, U., Olson, S.-O., 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. Prev. Vet. Med. 58, 179-197.

Svensson, C., Liberg, P., 2006. The effect of group size on health and growth rate of Swedish dairy calves housed in pens with automatic milk-feeders. Prev. Vet. Med. 73, 43-53.

Svensson, C., Linder, A., Olsson, S.-O., 2006. Mortality in Swedish dairy calves and replacement heifers. J. Dairy Sci. 89, 4769-4777.

Thomas, G.W., Jordaan, P., 2013. Pre-slaughter mortality and post-slaughter wastage in bobby veal calves at a slaughter premises in New Zealand. New Zeal. Vet. J. 61, 127-132.

Todd, S.E., Mellor, D.J., Stafford, K.J., Gregory, N.G., Bruce, R.A., Ward, R.N., 2000. Effects of food withdrawal and transport on 5- to 10-day-old calves. Res. Vet. Sci. 68, 125-134.

Torres-Medina, A., Schlafer, D.H., Mebus, C.A., 1985. Rotaviral and coronaviral diarrhoea. Vet. Clin. North Am. Food Anim. Pract. 1, 471-93.

Trotz-Williams, L.A., Martin, S.W., Leslie, K.E., Duffield, T., Nydam, D.V., Peregrine, A.S., 2007. Calf-level risk factors for neonatal diarrhea and shedding of Cryptosporidium parvum in Ontario dairy calves. Prev. Vet. Med. 82, 12-28.

Trotz-Williams, L.A., Martin, S.W., Leslie, K.E., Duffield, T., Nydam, D.V., Peregrine, A.S., 2008. Association between management practices and within-herd prevalence of Cryptosporidium parvum shedding on dairy farms in southern Ontario. Prev. Vet. Med. 83, 11-23.

Trunkfield, H.R., Broom, D.M., 1990. The welfare of calves during handling and transport. Appl. Anim. Behav. Sci. 28, 135-152.

Uetake, K., Tanaka, T., Sato, S., 2011. Effects of haul distance and stocking density on young suckling calves transported in Japan. Anim. Sci. J. 82, 587-590.

Uetake, K., 2013. Newborn calf welfare: A review focusing on mortality rates. Anim. Sci. J. 84, 101-105.

Uys, J., Lourens, D.C., Thompson, P.N., 2011. The effect of unrestricted milk feeding on the growth and health of Jersey calves. J. S. Afr. Vet. Assoc. 82, 47-52.

van der Fels-Klerx, H.J., Horst, H.S., Dijkhuizen, AA., 2000. Risk factors for bovine respiratory disease in dairy youngstock in The Netherlands: the perception of experts. Livest. Prod. Sci. 66, 35-46.

Vannucchi, C.I., Rodrigues, J.A., Silva, L.C.G., Lucio, C.F., Veiga, G.A.L., 2015. Effect of dystocia and treatment with oxytocin on neonatal calf vitality and acid-base, electrolyte and haematological status. Vet. J. 203, 228-232.

Vasseur, E., Pellerin, D., De Passillé, A.M., Winckler, C., Lensink, B.J., Knierim, U., Rushen, J., 2012. Assessing the welfare of dairy calves: Outcome-based measures of calf health versus input-based measures of the use of risky management practices. Anim. Welfare. 21, 77-86.

Večerek, V., Šímová, M., Malena, M., Voslářová, E., Malena, M jr., 2006. Effect of calf diseases on mortality during transport for slaughter. Acta Vet. Brno. 75, 625-630.

Virtala, A.M., Mechor, G.D., Gröhn, Y.T., Erb, H.N., 1996. Morbidity from nonrespiratory diseases and mortality in dairy heifers during the first three months of life. J. Am. Vet. Med. Assoc. 208, 2043-2046.

Waltner-Toews, D., Martin, S.W., Meek, A.H., 1986a. The effect of early calfhood health status on survivorship and age at first calving. Can. J. Vet. Res. 50, 314-317.

Waltner-Toews, D., Martin, S.W., Meek, A.H. 1986b. Dairy calf management, morbidity and mortality in Ontario Holstein herds. II. Age and seasonal patterns. Prev. Vet. Med. 4, 125-135.

Wathes, D., Brickell, J., Bourne, N., Swali, A., Cheng, Z., 2008. Factors influencing heifer survival and fertility on commercial dairy farms. Animal. 2, 1134-1143.

Weary, D. M., 2001. Calf management: improving calf welfare and production. Adv. Dairy Technol. 13, 107-118.

Weaver, D.M., Tyler, J.W., VanMetre, D.C., Hostetler, D.E., Barrington, G.M., 2000. Passive transfer of colostral immunoglobulins in calves. J. Vet. Intern. Med. 14, 459-577.

Windeyer, M.C., Leslie, K.E., Godden, S.M., Hodgins, D.C., Lissemore, K.D., LeBlanc, S.J., 2012. The effects of viral vaccination of dairy heifer calves on the incidence of respiratory disease, mortality, and growth. J. Dairy Sci. 95, 6731-6739.

Windeyer, M.C., Leslie, K.E., Godden, S.M., Hodgins, D.C., Lissemore, K.D., LeBlanc, S.J., 2014. Factors associated with morbidity, mortality, and growth of dairy heifer calves up to 3 months of age. Prev. Vet. Med. 113, 231-240.

Wudu, T., Kelay, B., Mekonnen, H.M., Tesfu, K., 2008. Calf morbidity and mortality in smallholder dairy farms in Ada'a Liben district of Oromia, Ethiopia. Trop. Anim. Health Prod. 40, 369-376.

1.2 Case control study

Materials and methods

Because calf mortality is a rare event, a case control design was selected as the most appropriate way to explore risk factors for mortality associated with the farm, transport and processing stages of the dairy calf supply chain. Calves (cases – dead/condemned, controls) were selected by MPI Verification Services (VS) veterinarians at the processing plants and their management from the farm to the point of arrival at the plant traced back using questionnaires completed by interviewing the supplier of the calf (farmer) and transporter of the calf as soon after the event as possible and by recording features of processing at the plant. The study was double-blinded, meaning that neither the researchers nor the farmers/transporters knew at the time of interview whether the calf was a case (i.e. had died or been condemned) or a control.

In order to collect information on case and control calves, the researchers spent three non-consecutive weeks in each of six different regions across New Zealand in the 2016 bobby calf season, with one week spent in each region in the start, peak and end of the season (Table 1). Data were collected from the 27th June to 29th October 2016.

On each day of the week in a particular region, the veterinarians associated with the meat processing plant or plants involved in the study (Table 1) selected calves to be included (see Selection of case and control calves, below) and completed a pro forma for each control or case calf (Appendices 3 and 4), recording details such as breed and sex. In 2016, all calves that died or were condemned were subject to post mortem examination, therefore the case calf questionnaire included a section that captured details and findings of post-mortem examination. For the purposes of the research, additional guidelines were provided to the veterinarians to assist with completion of the case calf form and the post-mortem form to ensure consistency in reporting of the reason for condemnation and interpretation of results (Appendix 5).

The veterinarian then emailed the researcher the following information for each calf: supplier number, name, address and telephone number, and the transport company name, docket number and telephone number. Every processing plant was assigned a random number to ensure anonymity and confidentiality, as required by the Massey Human Ethics Committee.

The veterinarian did not indicate whether the calf was a case or control. This information was collected only after the questionnaire had been completed.

Table 1 Study week and location of region in which premises processing case and control calves were visited.

Rotation	Study week	Region	Number of premises visited
1	1	Bay of Plenty	1
	2	Waikato	2
	3	Manawatu-Wanganui	2
	4	Otago	1
	5	Canterbury	2
	6	Taranaki	1
2	7	Bay of Plenty	1
	8	Waikato	3
	9	Manawatu-Wanganui; Hawkes Bay	2
	10	Southland	4
	11	Canterbury	2
	12	Taranaki	2
3	13	Bay of Plenty; Northland	2
	14	Waikato	3
	15	Manawatu-Wanganui	3
	16	Canterbury; Otago	4
	17	Tasman; West Coast	2
	18	Southland	4

Following receipt of the details of the selected calves, one researcher contacted the associated supplier by phone to request participation in the research and arrange a farm visit. When contacting the supplier a standardised message introducing the researchers and explaining the purpose of the study was used (Appendix 6). If the supplier agreed, the researchers travelled to the farm of origin the next day to conduct the interview.

After visiting the farm, the livestock transport operator that collected the calf from the farm and delivered it to the processing plant was contacted. Transport operators were usually contacted at the end of the week once all farm visits that week had been completed. The reason was two-fold: (i) often one transport operator had been responsible for visiting multiple farms that week and the paperwork for all calves associated with that operator could be completed during one telephone call, and (ii) farm visits regularly ran late into the day and no one was contactable at the transport company when visits had been completed.

At the end of each week in the region, the researchers collected, either in person or by email, the case and control forms from the plant(s), as well as the post-mortem forms for the case calves. Interviews with personnel at the processing plants were carried out only once per plant during the season.

Selection of case and control calves

When more than one plant in a region was participating in the study, calves were selected at each plant on alternating days in the week the researchers were in the region. A case calf was one that was classified and recorded as either dead on arrival (DOA), condemned on arrival (COA), dead in yard (DIY) or condemned in yard (CIY). All calves that died or were condemned at a processing plant on its allocated day(s) during the week that the researchers were in the region were included in the study.

Up to 10 control calves per day were randomly selected from those classified as ‘acceptable’ in accordance with the ‘MPI VS Animal Welfare Procedure for Bobby Calves’ 2016 document. Acceptable calves were those that were: (1) 4 days old, (2) had an umbilicus that was wrinkled, withered shrivelled, and (3) were in good health, mobile, active, bright in the eye, and ears upright. The numbers of control calves varied throughout the season depending on the number of consignments arriving at the processing plants. Only one control per consignment was selected on a given day. If no case calves were present on the allocated day then only control calves were selected. To ensure unbiased selection, control calves were chosen using a random number table provided to the veterinarian. The first single digit from the table was matched to the final digit on a control calf’s ear tag. If no match presented, the next number on the table was used.

Case and control calves were then assigned a unique identification number including the order and date of selection (e.g. the first case calf on the 12th July would have been 01/12/17). This number was included in the documentation sent to the researchers and was later used to link data collected from the transporter and supplier with that recorded, including whether the animal was a case or control.

Questionnaires

Three questionnaires were developed, one for each of the stages of the supply chain. The questionnaires were approved by the Massey University Human Ethics Committee (MUHEC SOB # 16/18). Interviewing and completion of the questionnaire was undertaken by a single researcher to reduce bias. The development of the questionnaires was informed by the systematic literature review and included feedback from industry partners and members of the project steering committee.

Farm questionnaire

The farm questionnaire included 99 questions, 77 closed and 22 open questions relating to details of on-farm bobby and replacement heifer calf management during the first week of life (Appendix 7). The questions focussed on the topics of calving, neonatal care, feeding, housing, health and collection for transport. The questions pertained to farm management as undertaken during the week the selected calf was sent to the processing plant. The farm questionnaire was based on a validated questionnaire that had been used previously in a Canadian study conjointly undertaken by the Université Laval, Agriculture and Agri-Food Canada, Valacta and the Université de Montréal (Vasseur et al., 2010) which identified the most important factors affecting successful dairy heifer rearing. The questionnaire took between 20 to 30 minutes to complete during a face-to face interview with the farm owner/ manager or calf rearer.

Transport questionnaire

The transport questionnaire included details of the calf's journey from the farm to the processing plant. The questionnaire included 35 questions, 29 closed and 6 open questions (Appendix 8). Excluded were the following, which were recorded in the farm questionnaire: (1) location of calves at time of collection, (2) loading facilities on the farm, (3) the presence of a member of farm staff at the time of collection. The questionnaire was conducted via telephone interview following completion of the farm questionnaire and pertained to transport as undertaken in the week the selected calf was transported to the processing plant. Interviews were completed with the dispatcher or driver, depending on the size of the company.

Processing plant questionnaire

The questionnaire included 62 questions, 53 closed and 9 open, pertaining to management as undertaken during the seven days prior (Appendix 9). The questionnaire was only administered once during the study period. Therefore, only information gathered about the plant that was relevant to all calves processed there across the whole season could be used in the case control study. For example, questions such as "*In the last seven days, was feed provided to bobby calves in lairage?"* could not be included, as they related to a practice undertaken during the week the questionnaire was completed and may not have reflected the practice undertaken on the day the case or control calf was received at the plant. Completion of the plant questionnaires took place either in person at the plant or via telephone interview.

Data management and analysis

The data were collected from suppliers (farmers), transporters, processors and veterinarians. Each of these groups answered different questions and the responses were collated in separate Microsoft Excel worksheets. The data from the suppliers, transporters and veterinarians related to a specific case or control calf and were linked by a unique calf identification number. The data from processors were not linked to a specific calf as they were collected only once during the study period. A full list of the variables in each of the three data sets, as well as a description of each variable, is provided in Appendix 12.

Data analysis comprised three components: 1) Calculation of summary statistics for all the variables; 2) Assessment of whether on-farm management of calves varied between replacement heifers and bobby calves and 3) Construction of a multivariable model to identify risk factors for bobby calf mortality. The multivariable model was required because the data were collected from an observational study and as such the associations among variables may be affected (i.e. confounded) by a third variable. Multivariable models provide a way to estimate the effect of a single factor whilst controlling for other variables.

All analyses, with the exception of the multivariable model with a random effect for region (see section of Risk factor analysis), were conducted in SAS Version 9.4 (SAS Institute Inc., Cary NC, USA). R Version 3.4.4 (R Core Team 2008) was used to run the multivariable model with random effect for region. Statistical significance was set at $P < 0.05$.

Summary statistics

Summary statistics were calculated for all variables in the farm, transporter, processor and veterinarian data sets. Categorical variable data were summarised using counts and percentages. The method used to summarise continuous variables varied depending on whether the data were normally distributed. Normally distributed data were summarised by means and standard deviation while non-normally distributed data were summarised by median, minimum, maximum and the 25th and 75th percentiles.

Assessment of whether on-farm management of calves varied between replacement heifers and bobby calves

Paired tests were used to assess whether on-farm management of calves varied between replacement heifers and bobby calves, as the outcome of interest was whether management differed between the two groups, rather than how each supplier managed each. The method used to assess statistical significance varied depending on the nature of the data. For continuous data, the paired t-test and the Wilcoxon signed-rank test were used for normally and non-normally distributed data, respectively. For binary categorical variables (e.g. whether or not bedding was changed between groups of calves) significance was assessed using McNemar's test. When the categorical variable had more than two response options (e.g. type of bedding in calf housing unit) a conditional logistic regression model was constructed and statistical significance assessed using the Deviance test statistic.

Identification of risk factors

The risk factor analysis involved two data sets. The first data set comprised all cases (n=38) and controls (n=156). The second included all controls (n=156) and only those cases that were condemned or died in lairage at the processing plant (n=18). The separate data sets were created to allow a better understanding of the significance of processor-related factors. Importantly, for calves that died or were condemned on arrival (DOA/COA), processing plant variables may not have been relevant/influenced the risk of being a case.

For each data set a multivariable model was constructed in a six step process. Firstly, a binary outcome variable was generated that was coded for whether the calf was a case or control and separate logistic regression models were then used to determine the association between mortality and each explanatory variable. The second step involved construction of a multivariable model that included all variables that were associated with the outcome at $P < 0.20$, with one exception. Specifically, there were two variables measuring time in season. The first measured time in season as weeks since the first calving on the farm of origin (Time in farm's season) and the second as weeks since the start of the processing at the plant where the calf was processed (Time in plant's season). Unsurprisingly, these variables were highly correlated so the decision was made to include the variable that represented time in season as weeks since first calving on farm (Time in farm's season), as the association was strongest for this variable.

Thirdly, a preliminary multivariable model was created by stepwise removal of the least significant variable (assessed using the Deviance test statistic) until all the remaining variables were statistically significant. The fourth step involved comparison of the models created with each of the two data sets described above. If a variable was significant in one model but not the other, it was returned to the model to allow comparison between the models. The fifth step was an assessment of whether the continuous variables modelled should be treated as linear. Finally, the base model for each data set was extended to include a random effect coding for region to account for the fact that data from the same region and plant were clustered.

Results

Data collection was completed by the 29th October 2016 and preliminary data analysis took place between November 2016 and February 2017.

Response rates

A total of 606 dairy farmers across New Zealand were contacted as suppliers of a selected calf. Of these, 199 farmers initially agreed to participate in the research. Three farmers cancelled prior to attendance due to issues arising on the farm: flooded milking parlour (n=1), short a member of staff (n=1), forgotten previous appointment for the day of visit (n=1). Two farmers did not show on arrival at the farm and were uncontactable, resulting in a final total of 194/606 farmers (32%) completing the questionnaire. The distribution of these farms is shown in Figure 1. Of the 194 farms that agreed to participate, 38 had supplied case calves and 154 had supplied control calves. Two farms had supplied two case calves each, thus there were 40 case calves in total. For each of these pairs of case calves, one was excluded from the analysis to avoid artificially increasing the weight and thus contribution of factors from those two events.

Seventy different transport operators transported selected calves during the study period, with two farmers transporting their own calves to the plant. Calf transport information was obtained from 38/70 transport companies, for a total response rate of 52.8%. The 38 respondents were responsible for transporting 99/194 (51%) selected calves. When a transporter was not contactable or did not agree to provide transport information for selected calves, the researchers were able to extract travel time for most calves from the transport docket at the processing plant. Thus travel time data were available for 185 calves (n=34 cases and n=151 controls).

Processing plant information was collected from a total of 32 premises during the study period, including 29 export meat processors and 3 pet food processors.

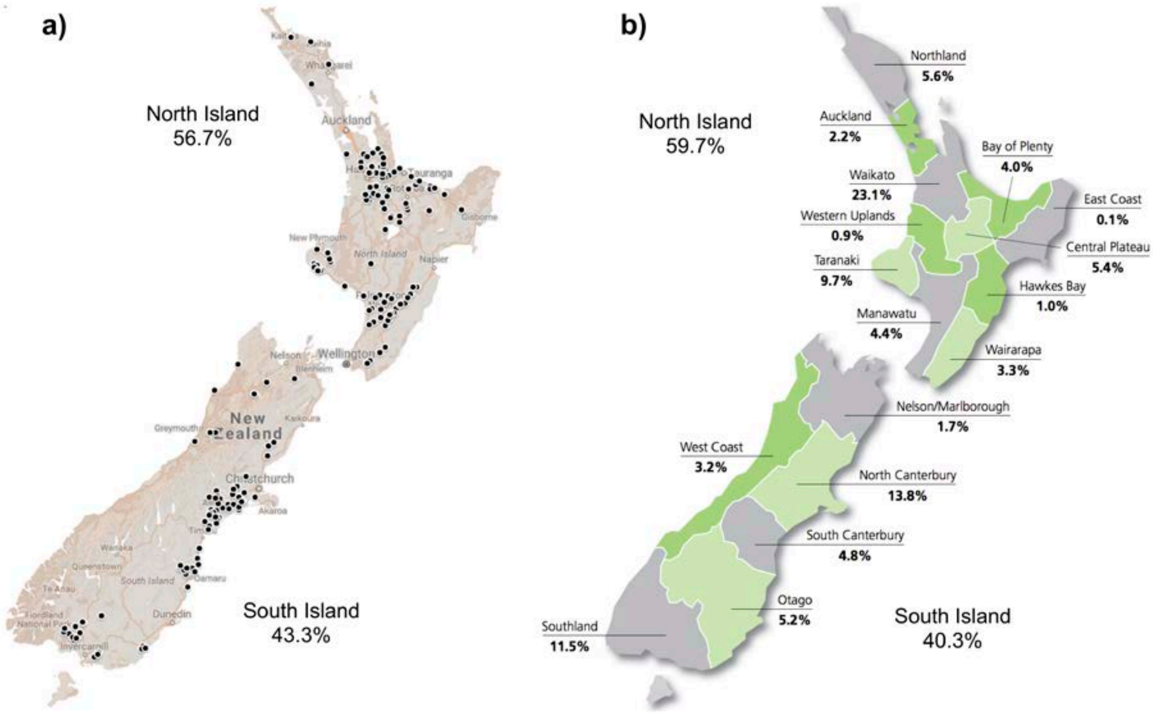

Figure 1 (a) Location of farms included in the study and (b) Distribution of dairy farms in New Zealand in 2015/16 (Source: LIC/DairyNZ New Zealand Dairy Statistics 2015/16).

Farm characteristics

Summary statistics for all farm variables collected in the survey are provided in Appendix 10. Briefly, of the farms included in this study, herd sizes ranged from 100 to 2,500 milking cows with a median herd size of 650 (IQR 515) cows. Only one farm visited was classified as organic and 90% were only involved in dairy (n=175). The 19 that were mixed enterprise included: beef (n=8), beef and sheep (n=5), kiwi fruit (n=2), arable (n=1), beef and deer (n=1), pigs (n=1) and sheep (n=1). The majority of farms were single block spring calving farms (92%) with only 8% operating as split autumn and spring calving. The most common operating structure on the farms visited were owner/equity partnership (n=118), with share milking operations (n=41) and contract milker/manager enterprises (n=35) less common. Of the 41 share-milking farms, 30 were 50/50 and 11 were lower order operations.

The predominant breeds present on the farms visited were Friesian/Friesian cross (n=97/194), Jersey/Jersey cross (n=20/194) and 'Other' including Kiwi cross (n=77/194). The category 'Other' also included different purebred and crossbred breeds such as Ayrshire, Ayrshire cross and Meuse Rhine Issel.

Transporter characteristics

A total of 70 livestock transport operators and two owners were responsible for transporting the 194 selected calves from the farm to the processing plant. The 38 operators (52.8%) who completed the transport questionnaire were responsible for transporting 99/194 (51%) selected calves, including seven case calves and 92 control calves.

Due to transport information being unavailable for 49% of selected calves, transport data could not be included in the risk factor analysis. A summary of the responses of the 38 transport operators is provided below.

All calves selected for the study were collected from the farm and delivered to the processing plant on the same day. More than half (55%) of livestock transporters allocated two members of staff to collect calves from the farm, a driver plus an assistant. Of the remainder, 42% employed only the driver to collect calves and 3% allocated three employees to the task. Most operators using multiple employees to collect calves returned their passengers to the depot before delivering the calves to the processing plant. Thus, on arrival at the plant, 72% of livestock trucks only had the driver to assist with the unloading of calves.

The mean (± standard deviation) number of calves per consignment (truck and trailer) was 137 ± 119 (range 10 to 499). The mean space allowance per calf was 0.28 ± 0.096 m^2. Fourteen percent of the 99 selected calves were transhipped during the transport process. Most transport operators (98%) used their depot or haulage yard to tranship calves, with the remainder making use of other locations such as livestock sale yards. The most common procedure (71%) for transhipping calves was to reverse the truck up to the largest truck or additional livestock trailer and walk calves across from one to the other. One livestock operator used a forklift and mobile pen to provide a bridge for calves to walk from one truck onto the trailer. The transhipping process took on average 38 ± 15.5 minutes to complete (range 10 to 60 minutes).

The mean travel time for all 194 selected calves from the farm to the processing plant was 3.4 ± 2.4 hours (range 0.1 to 10.0).

Processing plant characteristics

Personnel at 32 plants including 29 export meat processing plants and three pet food processing plants were interviewed: 24 of the interviews were completed in person and eight via telephone. Full descriptive statistics for all 32 processing plants surveyed are provided in Appendix 11. The descriptive results below only include data from the 29 export processing plants, as pet food plants did not provide case/control calves.

Most plants (23/29; 79.3%) began slaughtering bobby calves in July, with one plant starting in May, three in June and two in August. Approximately half (14/29; 48.3%) of the plants operated a same day slaughter schedule throughout the season. Three plants (10.3%) performed same day slaughter until near the end of the season, when they switched to a next day slaughter schedule.

CCTV was present and operational at 86.2% of plants (25/29) with 84% of these (21) covering unloading bays and the restraining/slaughter area. Between one and seven trucks could be unloaded simultaneously at the plants, with most ramps being automated (79%). Of the plants that had automated ramps, 65% (15/23) were set at or below 12°. Inspection of livestock trucks for cleanliness, stocking density and condition of the truck was undertaken at 93% of the plants. This included inspection by senior yardsmen, Plant Compliance and Animal Welfare Officers and third party auditors such as those from AsureQuality.

Every export processing plant had an induction training programme covering calf handling and welfare. Most plants conducted in-house training by the Animal Welfare or Compliance Officer (66%) with the remainder using AsureQuality (Animal Welfare Unit Standard 20644). The average (± SD) space allowance for bobby calves in lairage was 0.38 ± 0.13 m^2 (range 0.2 to 0.9 m^2).

Only nine (31%) of the plants regularly recorded the percentage of calves arriving wet at the plant and only seven (24%) recorded the number of calves arriving with scours. Seven (24%) plants had a nursery pen for calves that required attention on arrival at the plant, however only three of these recorded the number of calves placed in the nursery pen. Four (13.8%) plants reported feeding calves warm reconstituted milk powder in the nursery pen.

At all plants, the decision to condemn calves classified as ‘unacceptable’ on arrival (COA) was undertaken within three hours. In six (20.6%) plants, COA occurred immediately, and in a further eight (27.6%) this occurred within 30 minutes of arrival. All plants used captive bolt and thoracic stick to euthanase condemned calves; this was always undertaken by a member of staff trained in humane slaughter. The same method, undertaken by suitably qualified personnel, was used for condemning calves in yard.

Case calf characteristics

The 38 case calves were mostly male (n=25; 66%) and half (n=19) were Friesian/Friesian cross. Approximately half (n=18; 47.4%) were condemned on arrival and a further 10 (26.3%) were condemned at some point while in lairage (Table 2). Thus, nearly three quarters of case calves were condemned, rather than dying before the point of slaughter. Of the 10 calves that did die, most (8/10) died in the yards while waiting to be slaughtered, whilst two were dead on arrival at the plant.

Table 2 Number and percentage of calves that were dead on arrival (DOA), condemned on arrival (COA), dead in yard (DIY) and condemned in yard (CIY)

Classification	n	% of all cases (n=38)	% of selected calves (n=194)
DOA	2	5.3	1.0
COA	18	47.4	9.3
DIY	8	21.0	4.1
CIY	10	26.3	5.2
Total	38	100.0	19.6

The most frequently recorded reasons for condemnation were weakness, recumbency, thin body condition and dehydration (Table 3). Half of the calves condemned on arrival (9/18) were unable to walk off the truck.

Table 3 Reasons cited for condemnation of case calves (n=28)

Reason	Frequency	Percentage*
Weak	19	67.8
Recumbent	7	25.0
Thin Body Condition	4	14.3
Dehydration	3	10.7
Navel	2	7.1
Injured	2	7.1
Enteritis	1	3.6
Blind	1	3.6
Not recorded	3	10.7

* Calves could be condemned for more than one reason, therefore percentages do not add to 100

Approximately one third of post-mortem examinations completed on case calves recorded no significant findings (NSF; n=13/38; 34.2%). It should be noted that in some cases, NSF was recorded alongside other findings. The most frequently recorded other post-mortem findings were: diarrhoea (n=32/38, 84%), enteritis (n=8, 21%), inflamed umbilicus/urachus (n=6, 16%), musculature bruising (n=5, 13%) and peritonitis (n=4, 11%; Appendix 13). Two thirds (65.8%) of the calves examined were reported to have curd present in their abomasal content, one also had blood and another had fibre with the curd. Of the remaining calves, one had no curd, and the presence/absence of curd was not reported for 12 (31.6%).

Comparison of bobby calf and replacement heifer management on farm

Information was collected for 16 variables pertaining to on-farm calf management (Questions 39–41 and 47–50 in the farm questionnaire, Appendix 7). All farms surveyed housed both bobbies and replacement heifers in groups indoors, therefore these variables were omitted from analysis. Of the 14 variables considered further, only the type of milk, number of feeds per day, space allowance and days spent in the housing unit were significantly different between calf types (Table 4).

In terms of feeding, fewer farms fed bobby calves colostrum than fed it to replacements (5.7% of farms versus 7.2%, respectively). More farms (45%) fed bobby calves only once per day than fed replacements once per day (37%).

The average space allowance for bobby calves in the housing unit was lower (median 1.58, SD 1.22 m^2 per calf) than that of replacement heifer calves (median 1.75 $\pm$ 0.99 m^2 per calf).

Unsurprisingly, bobby calves spent fewer days in the housing unit (median 6, range 4–14 days) than did replacements (median 15.5, range 2–70 days).

Table 4 Results from statistical comparison of bobby and replacement calf management on New Zealand dairy farms (n=194)

Variable	Replacement	Bobby	P-value
Type of milk fed n (%)			0.022
Colostrum	14 (7.3)	11 (5.7)	
Transition	153 (79.3)	161 (83)	
Both	26 (13.4)	22 (11.3)	
Volume of milk per feed n (%)			0.197
≤ 2 Litres	70 (36.1)	74 (38.5)	
> 2 Litres/ad lib	124 (63.9)	118 (61.5)	
Number of milk feeds per day n (%)			0.007
1	37 (19.1)	45 (23.3)	
≥ 2/ad lib	157 (80.9)	148 (76.70)	
Type of feeding system n (%)			0.136
Automatic	2 (1.0)	0	
Cafeteria	7 (3.6)	6 (3.1)	
Dam	0	1 (0.5)	
Multi-teat	185 (95.4)	187 (96.4)	
Temperature of milk fed n (%)			1.0
Cold	50 (25.8)	46 (23.7)	
Warm	122 (62.9)	127 (65.5)	
Both	22 (11.3)	21 (10.8)	
Whether housing had solid walls or bars n (%)			0.423
Bars	174 (89.7)	173 (89.2)	
Solid	17 (8.8)	19 (9.8)	
Both	3 (1.5)	2 (1.0)	
Space allowance per calf (m^2) median (range)	1.75 (0.60–8.33)	1.58 (0.40–12.6)	0.0008
Age entering the housing unit (days) median (range)	1.00 (1–2)	1.00 (1–2)	0.18
Number of days spent in the housing unit n (%)			<0.0001
≤14 days	96 (49.5)	194 (100)	
>14 days	98 (50.5)	0	
Type of bedding provided n (%)			0.467
Wood substrate (shavings, chips, sawdust)	172 (88.7)	164 (74.5)	
Straw	11 (5.6)	17 (8.8)	
River stones	7 (3.6)	6 (3.1)	
Wooden slats (no cover)	4 (2.1)	7 (3.6)	
Frequency at which bedding is changed n (%)			0.456
Weekly	2 (1.0)	2 (1.0)	
Monthly	6 (3.1)	7 (3.6)	
1–2 times per season	166 (85.6)	167 (86.1)	
Every second year	16 (8.2)	13 (6.7)	
Never	4 (2.1)	5 (2.6)	
Frequency at which bedding is added n (%)			0.059
Weekly	26 (13.4)	30 (15.5)	
Fortnightly	7 (3.6)	8 (4.1)	
Monthly	15 (7.7)	16 (8.2)	
1–2 times per season	57 (29.4)	52 (26.8)	
Never	89 (45.9)	88 (45.4)	

Variable	Replacement	Bobby	P-value
Bedding changed between groups n (%)			0.103
Yes	7 (3.6)	3 (1.6)	
No	187 (96.4)	190 (98.4)	
Frequency at which housing is disinfected n (%)			0.055
Once per week or more	47 (24.2)	53 (27.3)	
Once per fortnight or less	147 (75.8)	141 (72.7)	

Risk factor analysis

The results of the univariate logistic regression analyses for those variables that had P-values ≤0.20 are provided below. Table 5 shows the results obtained using the data set containing all cases and controls, whilst Table 6 gives the results of the data set comprising all controls and the subset of 18 cases that died or were condemned in the yard (DIY/CIY). The screening results from all variables are provided in Appendix 14. There is some value to viewing the relationship between a single variable and risk of mortality, known as the unadjusted odds ratio; however, it is important to remember that the data have been obtained from an observational study and relationships can be confounded. Therefore, when it comes to discussing the impact of a particular variable we focus on the odds ratio obtained from the multivariable model, as the effects have been adjusted for other variables.

The results of the multivariable model for both data sets are shown in Table 7. Both data sets gave similar estimates for the effect of Weeks into farm’s season and Travel time on the odds of mortality. After adjusting for Travel time and plant Slaughter schedule, the odds of mortality increased by a factor of 1.2 for every additional week into the farm’s season. Similarly, for every additional hour travelled the odds of morality increased approximately 1.5 times. When using data from all cases and adjusting for Time in farm’s season and Travel time, the odds of mortality was 4 times higher when calves were processed at a plant with a next day slaughter schedule. However, when the data set was limited to those cases that died or were condemned in lairage the result was not significant.

Table 5 Results from univariate logistic regression analysis of explanatory variables for calf mortality using all cases and controls

Variable	Case calves (38)	Control calves (n=156)	Odds ratio (95% CI)	P-value
Farm location %				0.043
North Island	71	53	2.159 (1.001_4.655)	
South Island	29	47	REF	
Calving pattern %				0.032
Spring	84.2	94.2	REF	
Split	15.8	5.8	3.063 (1.018–9.214)	
Staff issues %				0.114
Yes	7.9	2.6	REF	
No	92.1	97.4	0.307 (0.066–1.434)	
Predominant weather				0.127
Dry	60.5	73.0	0.565 (0.269–1.185)	
Wet	39.5	27.0	REF	
Type of first colostrum				0.125
True	81.6	90.4	REF	
Mixed	18.4	9.6	2.123 (0.798–5.643)	
Colostrum quality tested				0.065
Yes	0	8.3	REF	
No	100	91.7	NC[1]	
Mean number of days spent in housing unit (range)	6.5 (4–11)	6.1 (4–14)	1.183 (0.950–1.472)	0.128
Age at separation from replacements %				0.015
Birth	52.6	63.5	1.185 (0.522–6.808)	
1–3 days old	39.5	18.6	4.827 (1.259–18.51)	
>3 days old	7.9	17.9	REF	
Location at time of collection %				0.012
Rearing pen/shed	60.5	48.1	0.307 (0.058–1.624)	
Elevated hutch	21.1	45.5	0.113 (0.019–0.655)	
Ground level hutch	10.5	4.5	0.571 (0.076–4.297)	
Trailer	7.9	1.9	REF	
Loading method %				0.029
Manually lifted	68.4	48.7	2.281 (1.075–4.841)	
Walk-on	31.6	51.3	REF	
Mean time in farm's season – weeks (range)	8.6 (2.0–13.3)	6.0 (0.1–18.0)	1.187 (1.079–1.306)	0.003
Travel duration –hours (range)	5.4 (0.75–10)	3.1 (0.1–10.0)	1.008 (1.004–1.001)	<0.001
Slaughter schedule %				<0.001
Same day	26.3	62.8	0.296 (0.105–0.831)	
Next day	73.7	37.2	REF	

Variable	Case calves (38)	Control calves (n=156)	Odds ratio (95% CI)	P-value
Truck inspection on arrival %				0.012
Yes	100	91	REF	
No	0	9	NC	
Who assesses calves on arrival				0.012
AQ staff	3	12	0.345 (0.041–2.902)	
MPI vet/AWO	0	3	NC	
Yard operator/supervisor	74	47	2.48 (1.087–5.662)	
Yard op/sup & MPI vet	23	38	REF	
When calf condition is assessed				0.022
Unloading	63	62	NC	
Unloading & penning	29	24	NC	
Unloading & ante mortem	8	3	NC	
Unloading, penning & ante mortem	0	11	REF	
Time in plant's season –weeks (range)	9.8 (3.7–20.0)	6.2 (0–20)	1.138 (1.021–1.269)	<0.001

REF = reference category; NC = Not Calculable due to there being no cases in one or more categories; AQ = AsureQuality; AWO=Animal Welfare Officer

[1] Data available for n=34 cases and n=151 controls

Table 6 Results from univariate logistic regression analysis of explanatory variables for calf mortality using all controls and a subset of cases that died or were condemned in the yard (DIY/CIY)

Variable	**Case calves (n=18)**	**Control calves (n=156)**	**Odds ratio (95% CI)**	**P-value**
Calving pattern %				0.032
Spring	77.8	94.2	REF	
Split	22.2	5.8	4.668 (1.273–17.11)	
Breed of calf			NC	0.077
Friesian/Friesian cross	78	51	NC	
Jersey/Jersey cross	11	12	NC	
Kiwi cross	11	33	NC	
Other	0	4	REF	
Mean number of staff caring for calves (range)	1.64 (1–4)	1.96 (1–6)	0.619 (0.309–1.213)	0.16
Staff issues %				0.118
Yes	11.1	2.6	REF	
No	89.9	97.4	0.211 (0.036–1.241)	
Age entering housing unit %				0.197
1 day old	94.4	99.4		
>1 day old	5.6	0.6	REF	
Mean number of days spent in housing unit (range)	6.9 (4–11)	6.1 (4–14)	1.314 (1.004–1.719)	0.039
Age at separation from replacements %				0.088
Birth	55.6	63.5	2.828 (0.347–23.05)	
1–3 days old	38.9	18.6	6.759 (0.780–58.53)	
>3 days old	5.5	17.9	REF	
Volume of first colostrum %				0.186
≤2 litres	39	55	0.514 (0.189–1.397)	
>2 litres/ad lib	61	45	REF	
Frequency of housing disinfection %				0.022
Daily	0	23	NC	
Weekly	11	6	2.222 (0.320–15.434)	
Fortnightly or less	72	52	1.605 (0.427–6.029)	
Never	17	19	REF	
Location at time of collection %				0.014
Rearing pen/shed	72.2	48.1	0.260 (0.040–1.710)	
Elevated hutch	16.7	45.5	0.063 (0.008–0.533)	
Ground level hutch	0.0	4.5		
Trailer	11.1	1.9	REF	

Variable	Case calves (n=18)	Control calves (n=156)	Odds ratio (95% CI)	P-value
Loading method %				0.059
Manually lifted	72.2	48.7	2.737 (0.931–8.044)	
Walk-on	27.8	51.3	REF	
Staff member present at collection %				0.132
Yes	33	52	REF	
No	67	48	0.463 (0.165–1.296)	
Mean time in farm's season – weeks (range)	8.5 (4.0–13.3)	6.0 (0.1–18.0)	1.165 (1.029–1.319)	0.012
Travel duration –hours (range)	5.4 (1.5–9.5)	3.1 (0.1–10.0)	1.600 (1.242–2.062)	<0.001
Slaughter schedule %				0.016
Same day	33.3	62.8	0.296 (0.105–0.831)	
Next day	66.7	37.2	REF	
Time in plant's season –weeks (range)	8.9 (3.7–20.0)	6.2 (0–20)	1.138 (1.021–1.269)	0.016

REF = reference category; NC = Not Calculable due to there being no cases in one or more categories; AQ = AsureQuality; AWO=Animal Welfare Officer

[1] Data available for n=34 cases and n=151 controls

Table 7 Results from a mixed effect multivariable model exploring risk factors for mortality using all cases and controls (n=194; 38 cases) and a subset of cases that died or were condemned in yard (DIY/CIY) (n=174; 18 cases). OR = adjusted odds ratio.

	All cases		**DIY/CIY cases only**	
Variable	OR (95% CI)	P-value	OR (95% CI)	P-value
Weeks since first calving on farm (per week)	1.21 (1.06–1.35)	0.003	1.21 (1.03–1.42)	0.022
Travel time (per hour)	1.44 (1.19–1.76)	0.0003	1.53 (1.17–2.01)	0.002
Plant slaughter schedule (next day vs same day)	3.82 (1.53–9.58)	0.005	2.80 (0.82–9.49)	0.103

A more detailed description of the those variables that were found to have a significant effect on calf mortality in the multivariate analyses is provided below.

Time in farm's season

On average, case calves (all cases) were collected and transported later in the farm's calving season (8.62 ± 3.04 weeks) than were control calves (5.98 ± 4.05 weeks). When cases were limited to DIY and CIY calves, the case calf average was 8.93 ± 4.51 weeks into the season.

Travel duration

On average, case calves (all cases) travelled for longer (5.38 ± 2.45 hours) than did control calves (3.11 ± 1.97 hours). When cases were limited to DIY/CIY, the average travel duration for case calves was 5.44 ± 2.43 hours.

Slaughter schedule

Of the 38 case calves, 30 (79%) died or were condemned at processing plants with a next day slaughter schedule, compared to only 37% of control calves (Table 8). When the data were restricted to death or condemnation in lairage, 67% of case calves were slaughtered at premises with a next day schedule.

Table 8 Frequency and percentage of case and control calves that died or were condemned at plants with same day or next day slaughter schedules. DIY=died in yard; CIY=condemned in yard.

	Slaughter schedule		
Classification	**Same day**	**Next day**	**Total**
All cases	8 (21.05%)	30 (78.95%)	38
DIY/CIY cases	6 (33.3%)	12 (66.7%)	18
Control	98 (62.8%)	58 (37.2%)	156
Total*	106 (54.6%)	88 (45.4%)	194 (100%)

* DIY/CIY cases are a subset of all cases and are therefore excluded from the total

Discussion

Bobby calves must be at least four days of age when transported from the farm to the processing plant, and are typically between four and seven days of age. Codes of welfare mandate that calves be healthy, alert, able to bear weight evenly on all four limbs and have received at least half their day's feed ration within 2 hours prior to being transported. Their journey and lairage times are regulated, as is their time off feed. Despite all this, some calves still do not survive the journey to the processing plant or their time in lairage prior to slaughter, or are so seriously compromised that they are euthanased.

The bobby calf supply chain has three main stages: farm, transport and processing. Each of these stages has features that may increase the risk of morbidity and mortality for the calves. Three significant risk factors for mortality or condemnation were identified from this case-control study: the travel time from the farm to the processing plant; whether calves were slaughtered at a plant with a same day or next day slaughter schedule; and time into the farm's calving season.

Travel time

The present study provides evidence that calves travelling for longer from the farm to the plant were more likely to die or be condemned on arrival or in lairage, regardless of the time in the farm's calving season. For every additional hour of travel time, the risk of death or condemnation was 1.44 times higher and calves were 1.53 times more likely to die or be condemned in lairage. The increase in risk with travel time was linear, meaning that there was no threshold below which travel time would be safe; rather, any increase in travel time increased the risk, and shorter travel times posed lower risk.

There are multiple possible reasons for the observed effect of travel time on calf mortality. Transportation of young animals from the farm to the plant imposes stresses that affect their biochemical, hormonal and metabolic status (Trunkfield and Broom, 1990). Long journey times (Cave et al., 2005; Večerek, et al., 2006; Uetake et al., 2011), loading and unloading (Kent, 1986; Cave et al., 2005), novel human-animal contact (Lensink et al, 2001), and the inability of animals to lie down (Uetake et al., 2011) have all been shown to negatively affect the health and welfare of the calf. While Cave et al. (2005), Večerek, et al. (2006) and Uetake et al. (2011) all used journey distance rather than travel time as their recorded variable, it can be expected that a longer journey distance equates to longer travel time. All three studies found that longer journeys impacted adversely on the health and increased the mortality rate of calves. The reported relationships between travel time/distance and metabolic status suggests that travel time may be a proxy for time off feed.

In the current study, transport time was the only transport-related factor that was associated with increased risk of mortality. While it is possible that this is the only factor of importance, it is important to note that collecting detailed data about calf transportation was difficult. As such, the possible occurrence of measurement errors that could result in non-significance of other transport factors cannot be ruled out. Furthermore, insufficient information was provided by most transport operators to determine transport stocking density and no information about temperature, ammonia levels or the number of stops was available. Given that bobby calves will always have to be transported some distance for processing, further research should focus on identification of transport factors that alter the risk of mortality and animal welfare status, which may mitigate the risk posed by transportation.

Time in farm's calving season

Calves collected later in the calving season of the farm from which they originated were more likely to die or be condemned on arrival or in lairage. The persistence of this variable in the multivariate model that also included other farm and transport variables, rather than 'time in the plant's slaughter season', suggests that the effect is due to some feature of the farms which changes over the duration of their season. In addition, the fact that this effect on mortality remained after accounting for the other significant factors (e.g. it was significant regardless of travel time or plant's slaughter schedule) indicates that it was not seasonal changes in travel time that accounted for this seasonal effect.

When considered in light of the proposed causes of mortality in case calves (see below), it is possible that seasonal changes in farm management, which alter the likelihood of gastrointestinal infection or of nutritional scouring, may contribute to the seasonal effect on mortality. Such changes might include alterations in staffing or staff behaviour, or in features of bobby calf management. An example of the latter might be bedding management, such that pathogen load might increase as the farm's calving season progresses, increasing the risk of infection later in the season. Although no significant associations were found between farm variables such as frequency of bedding change or housing cleaning/disinfection and calf mortality in the present study, it should be noted that the number of case calves was relatively small (n=38 for all cases and n=18 for lairage cases). Given that the frequency of cleaning/disinfection of bobby calf housing varied from daily (6% of farms) to never (22% of farms) and the frequency of bedding change ranged from weekly (1% of farms) to every second year (7% of farms), the associations between time in the farm's season and such factors may warrant further investigation.

Slaughter schedule

The impact of a next day slaughter schedule on the odds of mortality was unclear. When analysing data from all cases (n=38), the results indicated an approximately 4-fold increase in risk of mortality when the processor had a next day slaughter schedule. When cases were limited to those calves that were condemned or died in the yards (n=18), there was no significant effect of slaughter schedule on mortality. This was unexpected, given that we had limited the cases to those most likely to be impacted by a policy of next day slaughter. There are two main reasons why this may have occurred. Firstly, calves that were dead or condemned on arrival included animals that died/were condemned within two hours of arrival. It is plausible that processors who were slaughtering next day would be more likely to condemn a 'borderline' animal to minimise suffering and/or to have the death associated with transport rather than the processing plant. Secondly, we may not have detected an association in the restricted data set (DIY/CIY cases only) because of a lack of statistical power as there were only 18 cases. A post hoc power analysis estimated that the power to detect an association in the limited data set was relatively low (0.43). It is not possible to postulate as to which reason is more likely. Given that day of slaughter is something that could be modified, undertaking further research to determine the impact of slaughter schedule should be a priority. It is worth noting that young calf regulations that came into effect on 1 February 2017, specifying that calves must be slaughtered as soon as possible after arrival at the processing plant (MPI, 2016), are likely to have influenced plant slaughter policy since data collection in 2016.

Case calf health status and causes of mortality

Information about the health and disease status of the case calves selected for this study could only be sourced from condemnation and post-mortem records. The method of collecting data about risk factors after the event was the most appropriate way to address the research objectives, given the extremely low prevalence of death or condemnation of calves prior to slaughter. Furthermore, the study was designed in a way to minimise bias in measurement of risk factors by contacting suppliers and transporters within a week of the event and ensuring that both the researcher and interviewee were blinded to the whether the calf was a case or control. However, it was still not possible to obtain information about the disease status or age of calves from suppliers and transporters. Nonetheless, the condemnation and post-mortem data provide evidence that some feature or features of travel time, plant's slaughter schedule and time in a farm's calving season increased the risk of calves dying or being condemned.

The most frequent reasons for the condemnation of bobby calves were weakness, recumbency, thin body condition and dehydration. In addition, post-mortem examination revealed that most case calves (84%) showed signs of diarrhoea, with 20% also showing signs of enteritis. This is in agreement with the study of Thomas and Jordaan (2013) who reported that digestive tract disorders and omphalitis were the most common primary diagnoses in calves that died prior to slaughter. In that study, emaciation, mild diarrhoea, non-fatal trauma and milk in the rumen were commonly reported in condemned calves.

Diarrhoea can have a nutritional or pathogenic aetiology. Nutritional scours is often the result of changes in calf feeding and can weaken the calf if it continues without intervention. Infectious scours is the result of exposure to a pathogen and is most prevalent during the first three weeks of life (Waltner-Toews et al., 1986; Virtala et al., 1996; Trotz-Williams et al., 2007), which is when most bobby calves are sent to slaughter. Both can lead to dehydration, weakness, lethargy and recumbency. However, severe infectious diarrhoea also leads to acid-base and electrolyte derangements which, combined with severe dehydration, can be fatal (Walker et al. 1998; Smith 2009).

Comparison of bobby and replacement calf management on farm

In general, it appears that bobby calves and replacement heifer calves are managed similarly on New Zealand dairy farms. Whilst the method and type of housing, use and management of bedding, and cleaning/disinfection of housing did not differ between calf types, the average space allowance per calf in the housing unit was lower for bobby calves than for replacements. In terms of feeding regime, milk volume per day, milk temperature and type of feeding system did not differ between calf types, whereas the type of milk provided and the number of feeds per day were different. Replacement heifers were more likely to be fed colostrum than were bobby calves, whereas bobby calves were more likely to receive their daily milk allocation in a single feed. There may be implications of these early management differences in terms of bobby calf health and welfare, but further research is required.

References

Aly, S. S., Pithua, P., Champagne, J. D., & Haines and D. M. 2013. A randomized controlled trial on preweaning morbidity, growth and mortality in Holstein heifers fed a lacteal-derived colostrum replacer or pooled maternal colostrum. BMC Vet. Res. 9, 168.

Barrier, A.C., Haskell, M.J., Birch, S., Bagnall, A., Bell, D.J. and Dickinson, J., Macrae, A.I. and Dwyer, C.M. 2013. The impact of dystocia on dairy calf health, welfare, performance and survival. Vet. J. 195, 86-90.

Boulton, A.C., Rushton, J. and Wathes, D.C. 2015. A study of dairy heifer rearing practices from birth to weaning and their associated costs on UK dairy farms. OJAS. 5, 185-197.

Castro-Hermida, J.A., González-Losada, Y.A. and Ares-Mazás, E. 2002. Prevalence of and risk factors involved in the spread of neonatal bovine cryptosporidiosis in Galicia (NW Spain). Vet. Parasitol. 106, 1-10.

Cave, J.G., Callinan, A.P.L. and Woonton, W.K. 2005. Mortalities in bobby calves associated with long distance transport. Aust. Vet. J. 83, 82-84.

Fallon, R. and Harte, F. 1983. The occurrence of diarrhoea in calves under different management systems. Ann. Rech. Vet. 14, 473-478.

Gulliksen, S.M., Lie, K.I., Løken, T. and Østerås, O. 2009. Calf mortality in Norwegian dairy herds. J. Dairy Sci. 92, 2782-2795.

Lensink, B.J., Raussi, S., Voivin, X., Pyykkonen, M. and Veissier, I. 2001. Reactions of calves to handling depend on housing condition and previous experience with human. Appl. Anim. Behav. Sci. 70, 187-199.

LIC/Dairy NZ, 2013. New Zealand dairy statistics 2012/13. http://www.lic.co.nz/user/file/DAIRY%20STATISTICS%202012-13-WEB.pdf [accessed 01 May 2017]

Ministry for Primary Industries. 2015. MPI VS Animal Welfare Procedure for Bobby Calves.

Ministry for Primary Industries. 2017. Mortality rates in bobby calves 2008 to 2016. http://www.mpi.govt.nz/law-and-policy/legal-overviews/animal-welfare/animal-welfare-regulations/caring-for-bobby-calves/ [accessed April 2017]

MPI (Ministry for Primary Industries). 2016. Animal Welfare (Calves) Regulations 2016. Available at: http://legislation.govt.nz/regulation/public/2016/0170/latest/DLM6905457.html

National Research Council. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Priestley, D., Bittar, J.H., Ibarbia, L., Risco, C.A. and Galvão, K.N. 2013. Effect of feeding maternal colostrum or plasma-derived or colostrum-derived colostrum replacer on passive transfer of immunity, health, and performance of preweaning heifer calves. J. Dairy Sci. 96, 3247-3256.

R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org.

Razzaque, M.A., Al-Mutawa, T., Abbas, S. and Bedair, M. 2009. Performance of pre-weaned dairy calves under hot arid environment: Effects of immunoglobulins and age on diseases and mortality. Am. J. Appl. Sci. 6, 1885-1891.

Sexson, J.L., Wagner, J.J., Engle, T.E. and Eickhoff, J. 2011. Predicting water intake by yearling feedlot steers. J. Anim. Sci. 90, 1920-1928.

Smith, G. W. (2009). Treatment of calf diarrhea: Oral fluid therapy. Vet. Clin. North America: Food Animal Practice, 25 (1), 55-72.

Stafford, K.J., Mellor, D,J., Todd, S.E., Gregory, N.G., Bruce, R.A. and Ward, R.N., 2001. The physical state and plasma biochemical profile of young calves on arrival at a slaughter plant. New Zeal. Vet. J. 49, 142-149.

Thomas, G.W. and Jordaan, P. 2013. Pre-slaughter mortality and post-slaughter wastage in bobby veal calves at a slaughter premises in New Zealand. New Zeal. Vet. J. 61, 127-132.

Trotz-Williams, L.A., Martin, S.W., Leslie, K.E., Duffield, T., Nydam, D.V. and Peregrine, A.S. 2007. Calf-level risk factors for neonatal diarrhea and shedding of Cryptosporidium parvum in Ontario dairy calves. Prev. Vet. Med. 82, 12-28.

Trotz-Williams, L.A., Martin, S.W., Leslie, K.E., Duffield, T., Nydam, D.V. and Peregrine, A.S. 2008. Association between management practices and within-herd prevalence of

Cryptosporidium parvum shedding on dairy farms in southern Ontario. Prev. Vet. Med. 83, 11-23.

Trunkfield, H.R. and Broom, D.M. 1990. The welfare of calves during handling and transport. Appl. Anim. Behav. Sci. 28, 135-152.

Uetake, K., Tanaka, T. and Sato, S. 2011. Effects of haul distance and stocking density on young suckling calves transported in Japan. Anim. Sci. J. 82, 587-590.

Vasseur, E., Rushen, J., de Passillé, A.M., Lefebvre, D. and Pellerin. D. 2010. A Canadian intervention strategy to encourage changes in calves and heifers management to improve welfare in dairy farms. J. Dairy Sci. 93, 4414-4426.

Večerek, V., Šímová, M., Malena, M., Voslářová, E. and Malena, M jr. 2006. Effect of calf diseases on mortality during transport for slaughter. Acta Vet. Brno. 75, 625-630.

Virtala, A.M., Mechor, G.D., Gröhn, Y.T. and Erb, H.N. 1996. Morbidity from nonrespiratory diseases and mortality in dairy heifers during the first three months of life. J. Am. Vet. Med. Assoc. 208, 2043-2046.

Walker, P.G., Constable, P.D., Morin, D.E., Drackely, J.K., Foreman, J.H. and Thurmon, J.C. (1998). A reliable, practical and economical protocol for inducing diarrhea and severe dehydration in the neonatal calf. Can. J. Vet. Res. 62 (3), 205-213.

Waltner-Toews, D., Martin, S.W. and Meek, A.H. 1986. Dairy calf management, morbidity and mortality in Ontario Holstein herds. II. Age and seasonal patterns. Prev. Vet. Med. 4, 125-135.

Windeyer, M.C., Leslie, K.E., Godden, S.M., Hodgins, D.C., Lissemore, K.D. and LeBlanc, S.J. 2014. Factors associated with morbidity, mortality, and growth of dairy heifer calves up to 3 months of age. Prev. Vet. Med. 113, 231-240.

1.3 Conclusions and recommendations

Bobby calves are an inevitable by-product of the New Zealand dairy industry as it currently operates. Continued production of bobby calves will require ensuring that the quality of rearing, management, transport, lairage and slaughter of bobby calves is optimal to reduce morbidity and mortality.

A systematic review of the published literature identified disease and age of calf as the most commonly cited risk factors for mortality and morbidity in dairy calves across the supply chain. Although the review incorporated information from calves up to and, in some cases, beyond weaning, it is likely that disease is also a key risk factor in the New Zealand bobby calf context, given the high susceptibility of neonatal calves to enteric and respiratory infection. This is supported by post-mortem data collected by MPI Verification Services veterinarians from condemned calves in New Zealand, where enteric disorders, navel ill and enzootic pneumonia were prominent. Later in the supply chain, risk factors relating to metabolic exhaustion also appeared; these may reflect the time since calves last fed or proxies such as travel duration.

In order to comprehensively understand risk factors for bobby calf mortality across the complete New Zealand dairy supply chain, factors such as calf age and sex, disease incidence from farm to processing plant, on-farm nutrition management, transport duration, season/weather and indicators of the physical status of calves in lairage could be evaluated.

A case control study involving 194 calves identified time in farm of origin's calving season, travel duration and plant slaughter schedule as significant risk factors for bobby calf mortality in New Zealand dairy supply chain. While travel time and slaughter schedule can be regulated, time in season is more difficult. In fact, since these data were collected in the 2016 calving season new regulations have been introduced with regard to transport duration and slaughter policy. Regulations in force since August 2016 set the maximum travel duration at 12 hours for young calves, and since February 2017 calves are required to be slaughtered as soon as possible after arrival at the processing plant and within 24 hours of their last feed on farm. Although calving spread in New Zealand's pastoral based dairy system means it is not possible to regulate time in season, the identification of this as a risk factor provides some insight into factors of potential importance, as well as highlighting the value of limiting exposure to other risk factors later in the calving season. It is possible that education and extension within the industry could be effective in reducing animal welfare compromise and mortality associated with seasonal effects.

As the present study design did not permit us to obtain information of calf age or disease status, the influence of these factors on risk of mortality in calves requires further investigation.

Chapter 2: Prevalence of potential animal-based indicators of poor welfare status in New Zealand bobby calves

Improving animal welfare encompasses identifying issues that may influence the animal's welfare and promoting corrective measures that will benefit the animal (Barnett & Hemsworth, 2009). Concerns for the welfare of calves in the dairy industry, in particular bobby calves, have driven an interest in developing specific welfare assessment schemes. An array of health, behavioural and environmental parameters can potentially be used as indicators of animal welfare in such schemes (Mollenhorst et al., 2005). Such parameters include both resource-based (e.g. environmental and management factors) and animal-based measures. The systematic application of these kinds of parameters to welfare assessment may increase our understanding of bobby calf requirements, facilitate routine assessment of calf welfare in industry and support the development of policy and legislation to safeguard calf welfare (Edwards, 2007).

Parameters potentially indicative of animal welfare can be divided into resource-based indicators and animal-based indicators. Resource-based indicators describe features of the environmental surroundings and the management systems. Although resource-based indicators are not a direct assessment of an animal's welfare, they are factors relating to the environment which are considered to affect the welfare of an animal (Mollenhorst et al., 2005; AWIN, 2015). These indirect indicators relate to an animal's welfare by reflecting the suitability of inputs, including resources and management provision (Pritchard et al., 2005). Another way to think about resource-based indicators is in terms of informing the possible risks that may compromise or enhance an animal's welfare, rather than actually assessing the animal's welfare state (Rousing, et al., 2001; Pritchard, et al., 2005). In contrast, animal-based welfare indicators reflect more direct observations of an animal's reaction to a specific environment or management system (Mollenhorst, et al., 2005; Pritchard, et al., 2005).

The overall aim of this study was to determine the prevalence of proposed health and welfare indicators in bobby calves in lairage prior to slaughter at commercial meat processing plants in New Zealand.

Key research activities

1. Conduct a systematic review of the literature to identify potential resource- and animal-based indicators for use in assessing bobby calf welfare.

2. Conduct an observational study to determine the prevalence of selected health and welfare indicators in bobby calves in lairage prior to slaughter.

2.1 Systematic review of the published literature on potential indicators of welfare in bobby calves

Concerns around the welfare of bobby calves is not new and given the growing interest in identifying welfare compromise and enhancement in a practical sense (Edwards, 2007), as well as the broad scope of the research associated with animal welfare published to date, there is a need to recognise publications associated with this topic to identify the areas that have been previously analysed and understood as well as the areas where there are knowledge gaps. There is increasing work being done to identify indicators of negative and positive welfare states in production animals (e.g. Llonch, et al., 2015). However, there has not been a systematic mapping of the published literature on this subject. The use of systematic mapping provides a structured method to gather the research evidence required to outline and appraise the current literature surrounding calf welfare. The methodical systems used reduce bias when identifying and evaluating studies to be included in the review by following documented protocols that allow for repeatability (Sargent & O'Conner, 2014). Systematic mapping of the literature provides a defined library of the current information on which decisions can be made, as well as identifying areas where research could be conducted to improve knowledge (O'Connor & Sargeant, 2014).

This section presents a systematic mapping review of animal-based and ante-mortem indicators of welfare that could be used to assess the welfare of bobby calves in lairage at commercial abattoirs in New Zealand. The overall aim was to develop an understanding of the existing global research associated with identifying potential welfare indicators of calf welfare that could be used in a practical sense to monitor the calf welfare.

Materials and Methods

The question driving the systematic mapping was:

“What is the current state of published research related to neonatal animal welfare?”

To address the question a four step process was followed (see Figure 2). Step one was to systematically search the literature through selected databases. The second step was to screen the title and abstract from all the articles returned in the search for inclusion or exclusion. Step three was a full article screen where relevance was considered. The final step was to manually search the references of the returned articles and retrieve any deemed relevant to bobby calf welfare.

Search procedure

To identify potential resource- and animal-based indicators of calf welfare, a search of the published scientific literature was undertaken using the electronic databases Discover, Web of Science and Scopus. No restrictions were placed on year of publication or language. The following Boolean search terms were used:

neonate OR young OR veal OR bobby AND calf OR calv* OR cattle OR "dairy cal*" OR bovine OR "bos taurus" AND indic* OR sign* OR assess* OR evaluat* OR monitor* AND welfare

Eligibility criteria and selection of relevant articles

Articles that met the following criteria were included: academically published peer reviewed journal articles, conference proceedings, book chapters, thesis dissertations, systematic literature reviews or government reports; published in English. While all study types were considered, primarily, experimental and observational studies of calf welfare outlining either animal-based or resource-based welfare indicators were retrieved. Pre-screening indicated limited research in bobby calves specifically, therefore articles returned during the literature searches that outlined welfare indicators in other production animals were included. Similarly, to avoid excluding any potentially relevant indicators that have not yet been address in young calves, animals of different ages, not just neonates, were considered.

The first stage of the review process involved assessing articles for relevant titles or abstracts, and the irrelevant documents or duplicates were removed at this stage. Articles were deemed irrelevant if they were not looking at aspects of welfare that bobby calves may experience, for example pain behaviours due to husbandry procedures in lambs or the use of growth hormones in veal calves to induce growth. Articles that did not directly address potential indicators of welfare were deemed irrelevant at this point. Secondly, the references from all relevant articles were checked through a manual search to identify any articles that may be of use and were missed by the electronic search. The final screening of articles involved all relevant articles being assessed and the applicable information extracted and assembled into a simple database (Microsoft Excel). The final screening excluded articles that were not primary searches, i.e. narrative literature reviews, book chapters and government reports. The reference lists from the articles remaining after the primary screenings were re-analysed and relevant articles were included in the database.

Data extraction and evaluation

Relevant studies were examined and information was collected in order to identify animal-based and resource-based welfare indicators of calf welfare. The data extracted from the relevant articles included: authors, location of data collection (country and situation), year in which the study was conducted, year the article was published, the design of the study, the sample size and sampling methodology, and the indicator(s) of welfare on which the study focused.

The relevant indicators sourced from the returned literature were then categorised according to the four physical domains of welfare (‘Nutrition’, ‘Environment’, ‘Health’, ‘Behaviour’) as described in the Five Domains model, devised by Mellor & Reid (1994) and later extended by Mellor & Beausoleil (2015). These four domains focus on physical and/or functional disruptions to an animal’s nutritional and hydration status (Domain 1), physical and sensory environment (Domain 2) and health/function (Domain 3), as well as the animal’s behavioural interactions with the environment and other animals (Domain 4). The fifth domain, ‘mental state’ reflects the affective experiences which are consequences of four physical/functional domains and as such was not a category. Information about physical/functional changes, reflected by changes in the indicators observed, can then be used to cautiously draw conclusions about the animal’s mental experiences and thus its welfare state (Mellor and Beausoleil, 2015).

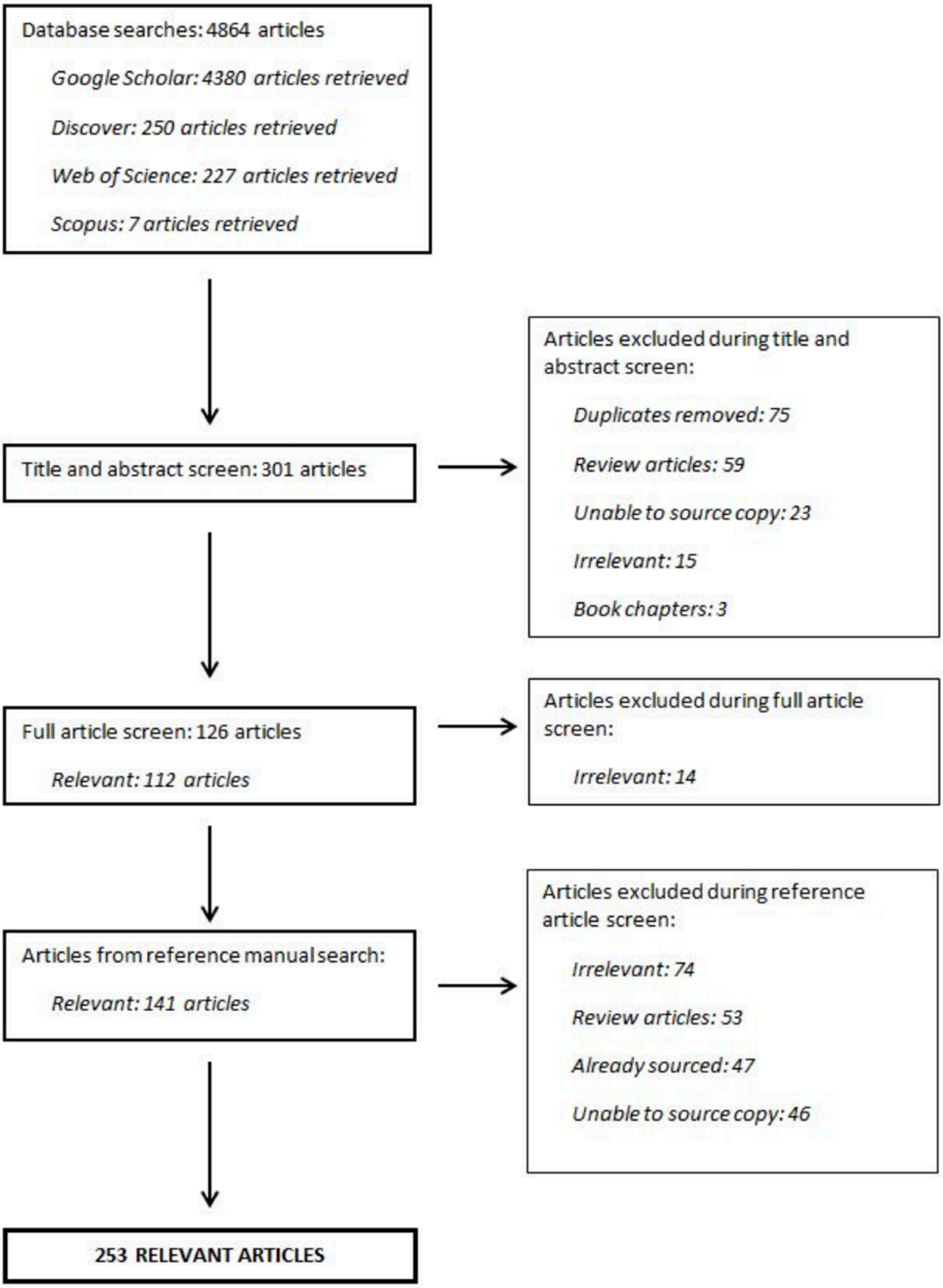

Figure 2 Outline of the systematic literature review process

Results

An outline of the search and retrieval process is provided in Figure 3. The initial electronic database searches returned a total of 4,864 articles. After reviewing the titles and abstracts of all returned articles, the number of relevant articles was reduced to 301 articles, or 6.2% of 4,864 articles initially retrieved. A further 75 were removed because they were duplicates (i.e. found in one or more database) leaving 226 original articles, or 4.6% of the 4,864 initially retrieved. When inclusion/exclusion criteria were applied to the 226 articles, 100 were removed because they were narrative review articles (n=59), the full text could not be retrieved (n=23), were irrelevant after subsequent consideration (n=15), or not primary publications (n=3). At the end of the process there were 126 articles describing welfare indicators, or 2.6% of those initially retrieved. Of the relevant articles, 13% (n=16) were retrieved by a single search engine, 51% (n=64) were retrieved by two search engines, and 36% (n=45) by all four search engines. A summary of the total number of articles returned, and the number of relevant articles sourced from each search engine is presented in Table 9.

At the secondary screening, which involved the articles being re-read and assessed for relevance, 14 articles were removed. The remaining 112 articles were then assessed and the references examined to determine any potentially relevant articles that may not have been returned in the initial database searches. Manual searching of the reference list recognised a further 361 potential articles addressing aspects of bobby calf welfare. The removal of articles that were already sourced in the initial search (n=47), irrelevant articles (n=74), narrative review articles (n=53) and those where the full article was unable to be sourced (n=46), resulted in 141 relevant publications. Thus, the final review consisted of 253 articles that were considered to contain relevant information regarding welfare indicators in young calves.

Table 9 Total number of publications and number of relevant articles retrieved from each database in the systematic literature review of potential calf welfare indicators

Database	Articles retrieved	Relevant Articles	Percentage accuracy
Web of Science	227	68	30
Scopus	7	4	57
Discover	250	83	33
Google Scholar	4380	102	2.3

The year in which relevant articles were published ranged from 1951 through to 2016. Of the relevant articles, more than half of these (53%) have been published during or after 2003 (Figure 3). Table 10 describes the classification of the studies, where the majority of relevant studies were prospective and conducted in cows (*Bos taurus*), with a range of population ages and sample sizes.

Table 10 Number and percentage of studies identified in the systematic literature review of potential calf welfare indicators, classifed by key features of study design

Category	Number of studies (%)
	(n=253)
Study design	
Cross-sectional: measurements made at a single point in time	52 (20.6)
Prospective: measurements taken as time progressed during the study	195 (77.1)
Retrospective: exposure and outcome determined before study	6 (2.4)
Country study conducted	
Unknown	68 (26.9)
USA	21 (8.3)
New Zealand	18 (7.1)
Canada	17 (6.7)
Australia	14 (5.5)
France	14 (5.5)
Italy	11 (4.3)
England	10 (4.0)
The Netherlands	9 (3.6)
Ireland	7 (2.8)
Spain	7 (2.8)
Denmark	6 (2.4)
Netherlands, France & Italy	6 (2.4)
Europe	5 (2.0)
Sweden	5 (2.0)
Germany	4 (1.6)

Category	Number of studies (%)
Japan	4 (1.6)
Switzerland	4 (1.6)
Austria	3 (1.2)
Chile	3 (1.2)
Scotland	3 (1.2)
Finland	2 (0.8)
Bangladesh	1 (0.4)
Belgium	1 (0.4)
Czech Republic	1 (0.4)
Netherlands	1 (0.4)
New Zealand & Canada	1 (0.4)
Norway	1 (0.4)
Poland to Italy	1 (0.4)
Serbia	1 (0.4)
Slovakia	1 (0.4)
Turkey	1 (0.4)
USA & Wales	1 (0.4)
USA, Canada & Australia	1 (0.4)
Animal species study conducted on	
Cows	217 (85.8)
Sheep	14 (5.5)
Pigs	9 (3.6)
Cows & Sheep	4 (1.6)
Buffalo	2 (0.8)
Cows & Pigs	2 (0.8)
Horses	2 (0.8)
Cows & Buffalo	1 (0.4)
Cows, Sheep & Goats	1 (0.4)
Quail	1 (0.4)
Age of Animal	
Unknown	38 (15.0)
≤3 weeks	66 (26.0)
3 weeks - 6 months	45 (17.8)
6 months - 1 year	25 (9.9)
>1 year	44 (17.4)
Numerous ages	35 (13.8)
Sample number	
Unknown	6 (2.4)
Individual animals:	
0 – 20	59 (23.3)

Category	Number of studies (%)
21 – 50	63 (24.9)
51 – 100	45 (17.8)
101 – 200	29 (11.5)
200 – 500	13 (5.1)
501 – 1000	5 (2.0)
1001 – 5000	6 (2.3)
5000+	5 (2.0)
Consignment of animals:	
0-100	9 (3.6)
100-200	7 (2.8)
200+	6 (2.3)

Welfare indicators

A total of 99 different welfare indicators were identified from the 253 articles reviewed (see Appendix 15, Tables 15.1–15.6 for a complete list of indicators). Almost half (48%) of the reviewed articles included indicators of nutritional/hydration status (Domain 1) and identified three different means of assessing welfare, including body weight (n=75), feeding (n=27) and water supply (n=9). Sixteen resource-based indicators and one animal-based indicator of welfare relating to the physical or sensory environment (Domain 2) were identified in the articles retrieved. Resource-based indicators included space allowance (n=28) and ambient temperature (n=39). Thirty-two indicators of health/functional status (Domain 3) were identified, including physiological parameters such as blood components (n=149), body temperature (n=48), heart rate (n=38), dehydration (n=19), diarrhoea (n=19), and nasal discharge (n=13). Finally, a total of 47 behavioural indicators reflecting animals' interactions with the environment, other animals and humans (Domain 4) were identified from the articles; these included oral behaviours (n=33), lying (n=55) and vocalising (n=25).

Discussion

This systematic mapping of the literature has provided a structured and comprehensible recognition of the primary characteristics of calf welfare from global research publications. The bobby calf industry is particularly relevant to New Zealand and Australia; the majority of the 253 studies identified were conducted in Europe, the United States and New Zealand. The search terms allowed for the identification of articles relating to bobby calves; however, inclusion criteria were not restricted and allowed for other neonatal animals and veal calves that are typically slaughtered at an older age. While neonates of other species may have different experiences compared to bobby calves, these studies helped to identify a range of potential welfare indicators that could then be assessed for validity, practicality, reliability and feasibility for use in the New Zealand bobby calf industry.

Gaining an international perspective on indicators used to evaluate welfare compromise and enhancement in young calves is valuable to better understand the published research and allows similarities and differences in the approaches to welfare evaluation to be compared across different countries. The geographical distribution of the search results plausibly represents production systems from industrialised regions where animal welfare science has been topical for many years (Fraser, 2008). However, the geographic distribution of research papers may also be due to the language restrictions placed on the acceptance of articles retrieved. The distribution of the articles agrees with other publications (e.g. Fraser, 2008; Fakoya, 2011) which indicated that, primarily in industrialised nations, the increase in production of meat from the 1960's has coincided with debates over the ethical treatment of animals and advances in science which refined and clarified the welfare issues (Fraser, 2008).

The research objective was to identify potential indicators of neonatal animal welfare; however, the diversity of the returned publications meant that results were not limited to neonates and studies involving welfare indicators in animals of numerous ages and types were returned. The selection of publications related to welfare assessed in a diverse range of facilities, including on farm, in commercial calving and veal systems, during transport, and at abattoirs. Accepting such articles allowed identification of a wider range of welfare indicators that may be valid and practical for assessment of bobby calf welfare.

Although mapping of the literature identified numerous indicators used to assess welfare in past studies, this exercise did not evaluate the validity, reliability, repeatability and feasibility of the indicators. Previous work has attempted to assess the validity of welfare indicators. For example, an investigation into the validity of various indicators used to evaluate sheep welfare at abattoirs was undertaken by Llonch and colleagues (2015). However, 'validity' in this evaluation was based upon reports of validity in the studies in which the indicator was originally used. More recent work to validate potential indicators of sheep welfare has been completed by Beausoleil & Mellor (2017). The authors suggest that rigorous validation requires evidence of the links between the indicator (e.g. behaviours observed) and physiological state (e.g. hydration status) and between the physiological state and the particular mental experiences that influence welfare status (e.g. thirst). Further research to investigate the validity of specific calf welfare indicators needs to be undertaken to provide a useful list of indicators that will encourage more detailed and holistic assessments in commercial facilities such as in abattoirs or during transportation.

Given the search terms used, it is not surprising that the majority of the studies gathered during the retrieval process were conducted on cows (87%). Because there is limited research regarding indicators of welfare in bobby calves, the inclusion of other species allowed a more comprehensive set of potential welfare indicators to be returned. It should be acknowledged that the inclusion of other species potentially weakens the accuracy and applicability of some of the indicators with respect to bobby calves in the current mapping. In contrast, there may be other welfare indicators discussed in different species, for example companion animals, which are not detected or addressed in the articles that were screened during the search. Likewise, a limitation of the search terms of the current mapping review is that it may have failed to identify welfare indicators that are potentially relevant for neonatal animals but have only been studied in adult animals. Articles were not excluded because of the age of the species in which the work was conducted unless the work was deemed irrelevant.

The nomenclature and descriptions of the welfare indicators included in the articles varies. For example, the behavioural indicator 'playing' is referred to as "play" in 17 of 253 articles. However other studies record different aspects of play, such as locomotor play, social play or object play. An example of locomotor play is jumping, which was recognised in 7 further articles. Categorisation of behaviours was partially dependant on the definition given of the specific behaviour, which is why the potential behavioural indicators are presented as they were recorded in each article.

During the search process, screening of the returned articles included primarily quantitative research: experimental studies, observational studies and systematic reviews, but rejected narrative literature reviews and reports not based on experimental data. A potential limitation of the use of the search engines is missing relevant literature that is either unpublished or in the form of a report. The selection of search engines was based on discussion with librarians who specialise in literature researching. It is interesting to note that searching of the references returned more relevant articles than the initial search. This further illustrates the limitations of the search terms used.

Although the resulting literature comprised scientific experiments and observational studies, there is a concern about the accuracy of the results in some publications due to the small sample sizes used. For example, Locatelli and colleagues (1989) looked at the adrenal response to simulated transport in three calves. While the experiment was conducted in order to assess blood constituents as indicators of stress, the use of such a small sample size carries a high risk of misinterpretation of the results.

The primary limitation in conducting a mapping of the literature is human error. The amount of literature returned in the search was extensive, and ensuring all data were accurately recognised and entered into the database was essential. The 253 relevant articles addressed in this systematic mapping were reviewed numerous times in order to collect results and gain a better understanding of the literature.

A selection of the potential welfare indicators identified by this systematic mapping were subsequently applied to an observational study of bobby calf welfare in lairage facilities across New Zealand.

References

Abdelfattah, E. M., Schutz, M. M., Lay, D. C., Marchant-Forde, J. N., & Eicher, S. D. (2013). Effect of group size on behavior, health, production, and welfare of veal calves. Journal of Animal Science, 91 (11), 5455-5465.

Ahsan, M., Hasan, B., Algotsson, M., & Sarenbo, S. (2014). Handling and welfare of bovine livestock at local abattoirs in Bangladesh. Journal of Applied Animal Welfare Science, 17 (4), 340-353.

Albright, J. (1983). Our industry today-state of animal welfare awareness of producers and direction of animal welfare research in the future. Journal of Dairy Science 66, 2208-2220.

Amadori, M., Archetti, I. L., Frasnelli, M., Bagni, M., Olzi, E., Caronna, G., et al. (1997). An immunological approach to the evaluation of welfare in Holstein Frisian cattle. Zoonoses and Public Health, 44 (1-10), 321-327.

Ames, D. R., & Insley, L. W. (1975). Wind-chill effect for cattle and sheep. Journal of Animal Science, 40 (1), 161-165.

Andreasen, S. N., Wemelsfelder, F., Sandøe, P., & Forkman, B. (2013). The correlation of Qualitative Behavior Assessments with Welfare Quality® protocol outcomes in on-farm welfare assessment of dairy cattle. Applied Animal Behaviour Science, 143 (1), 9-17.

Arskey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. International Journal of Social Research Methodology, 8 (1), 19-32.

Arthington, J. D., Eicher, S. D., Kunkle, W. E., & Martin, F. G. (2003). Effect of transportation and commingling on the acute phase protein response, growth, and feed intake of newly weaned beef calves. Journal of Animal Science, 81 (5), 1120-1125.

Averos, X., Herranz, A., Sanchez, R., Comella, J. X., & Gosalvez, L. F. (2007). Serum stress parameters in pigs transported to slaughter under commercial conditions in different seasons. Veterinarni Medicina, 52 (8), 333-342.

AWIN. (2015). AWIN Welfare Assessment Protocol for Sheep. doi:10.13130/AWIN_SHEEP_2015.

Bähler, C., Steiner, A., Luginbühl, A., Ewy, A., Posthaus, H., Strabel, D., et al. (2012). Risk factors for death and unwanted early slaughter in Swiss veal calves kept at a specific animal welfare standard. Research in Veterinary Science, 92 (1), 162-168.

Barnett, J., & Hemsworth, P. (2009). Welfare monitoring schemes: Using research to safeguard welfare of animals on the farm. Journal of Applied Animal Welfare Science 12, 114-131.

Barrier, A. C., Haskell, M. J., Birch, S., Bagnall, A., Bell, D. J., Dickinson, J., et al. (2013). The impact of dystocia on dairy calf health, welfare, performance and survival. The Veterinary Journal, 195 (1), 86-90.

Beausoleil, N. J., & Mellor, D. J. (2017). Validating indicators of sheep welfare. In J. (. Greyling, Achieving Sustainable Production of Sheep (pp. 327-348). Cambridge, UK: Burleigh Dodds Science Publishing.

Becker, B. A., Mayes, H. F., Hahn, G. L., Nienabers, J. A., Jesse, G. W., Anderson, M. E., et al. (1989). Effect of fasting and transportation on various physiological parameters and meat quality of slaughter hogs. Journal of Animal Science, 67 (2), 334-341.

Bergman, M. A., Richert, R. M., Cicconi-Hogan, K. M., Gamroth, M. J., Schukken, Y. H., Stiglbauer, K. E., et al. (2014). Comparison of selected animal observations and management practices used to assess welfare of calves and adult dairy cows on organic and conventional dairy farms. Journal of Dairy Science, 97 (7), 4269-4280.

Bernardini, D., Gererdi, G., Peli, A., Nanni Costa, L., Amadori, M., & Segato, S. (2015). The effects of different environmental conditions on thermoregulation and clinical and hematological variables in long-distance road-transported calves. Journal of Animal Science, 90 (4), 1183-1191.

Blaxter, K. L., & Wood, W. A. (1951). The metabolism of the calf during starvation and subsequent realimentation. British Journal of Nutrition, 5, 29-55.

Blecha, F., Boyles, S. L., & Riley, J. G. (1984). Shipping suppresses lymphocyte blastogenic responses in Angus and Brahman× Angus feeder calves. Journal of Animal Science, 59 (3) , 576-583.

Boissy, A., Veissier, I., & Roussel, S. (2001). Behavioural reactivity affected by chronic stress: an experimental approach in calves submitted to environmental instability. Animal Welfare, 10, 175-185.

Bokkers, E. A., & Koene, P. (2001). Activity, oral behaviour and slaughter data as welfare indicators in veal calves: a comparison of three housing systems. Applied Animal Behaviour Science, 75 (1), 1-15.

Bokkers, E. A., Leruste, H., Heutinck, L. F., Wolthuis-Fillerup, M., Van Der Werf, J. T., Lensink, B. J., et al. (2009). Inter-observer and test-retest reliability of on-farm behavioural observations in veal calves. Animal Welfare, 18 (4), 380-390.

Bourguet, C., Deiss, V., Gobert, M., Durand, D., Boissy, A., & Terlouw, E. C. (2010). Characterising the emotional reactivity of cows to understand and predict their stress reactions to the slaughter procedure. Applied Animal Behaviour Science, 125 (1), 9-21.

Bourguet, C., Deiss, V., Tannugi, C. C., & Terlouw, E. C. (2011). Behavioural and physiological reactions of cattle in a commercial abattoir: Relationships with organisational aspects of the abattoir and animal characteristics. Meat science, 88 (1), 158-168.

Braun, J. P., Tainturier, D., Laugier, C., Benard, P., Thouvenot, J. P., & Rico, A. G. (1982). Early Variations of Blood Plasma Gamma-Glutamyl Transferase in Newborn Calves—A Test of Colostrum Intake1. Journal of Dairy Science, 65 (11) , 2178-2181.

Broom, D. (1991). Animal welfare: Concepts and measurement. Journal of Animal Science 69, 4167-4175.

Brown-Brandl, T. M., Eigenberg, R. A., Nienaber, J. A., & Hahn, G. L. (2005). Dynamic response indicators of heat stress in shaded and non-shaded feedlot cattle, Part 1: Analyses of indicators. Biosystems Engineering, 90 (4), 451-462.

Brščić, M., Gottardo, F., Leruste, H., Lensink, J., Van Reenen, K. C., & Cozzi, G. (2011). Prevalence of locomotory system disorders in veal calves and risk factors for occurrence of bursitis. Agriculturae Conspectus Scientificus, 76 (4), 291-295.

Brščić, M., Leruste, H., Heutinck, L. F., Bokkers, E. A., Wolthuis-Fillerup, M., Stockhofe, N., et al. (2012). Prevalence of respiratory disorders in veal calves and potential risk factors. Journal of Dairy Science, 95 (5), 2753-2764.

Buckham Sporer, K. R., & Weber, P. S. (2008). Transportation of young beef bulls alters circulating physiological parameters that may be effective biomarkers of stress. Journal of Animal Science, 86 (6), 1325-1334.

Buckham Sporer, K. R., Burton, J. L., Earley, B., & Crowe, M. A. (2007). Transportation stress in young bulls alters expression of neutrophil genes important for the regulation of apoptosis, tissue remodeling, margination, and anti-bacterial function. Veterinary Immunology and Immunopathology, 118 (1-2), 19-29.

Budzynska, M., & Weary, D. M. (2008). Weaning distress in dairy calves: effects of alternative weaning procedures. Applied Animal Behaviour Science, 112 (1), 33-39.

Cabello, G., Michel, M. C., Foucher, C., & Lafarge, C. (1977). Composition of blood plasma (calcium, phosphorus, magnesium, proteins) during the neonatal period in the calf. Influence of the state of health. Annales de Recherches Vétérinaires, 8 (3) , 203-211.

Cafazzo, S., Magnani, D., Calà, P., Razzuoli, E., Gerardi, G., Bernardini, D., et al. (2012). Effect of short road journeys on behaviour and some blood variables related to welfare in young bulls. Applied Animal Behaviour Science, 139 (1), 26-34.

Candiani, D., Salamano, G., Mellia, E., Doglione, L., Bruno, R., Toussaint, M., et al. (2008). A combination of behavioral and physiological indicators for assessing pig welfare on the farm. Journal of Applied Animal Welfare Science, 11 (1), 1-13.

Cave, J. G., Callinan, A. P., & Woonton, W. K. (2005). Mortalities in bobby calves associated with long distance transport. Australian Veterinary Journal, 83 (1-2) , 82-84.

Clapp, J. B., Croarkin, S., Dolphin, C., & Lyons, S. K. (2015). Heart rate variability: a biomarker of dairy calf welfare. Animal Production Science, 55 (10), 1289-1294.

Cockram, M. S., Kent, J. E., Waran, N. K., McGilp, I. M., Jackson, R. E., Amory, J. R., et al. (1999). Effects of a 15h Journey Followed by Either I2h Starvation Or ad Libitum Hay on the Behaviour and Blood Chemistry of Sheep. Animal Welfare, 8 (2), 135-148.

Cole, N. A., Phillips, W. A., & Hutcheson, D. P. (1986). The effect of pre-fast diet and transport on nitrogen metabolism of calves. Journal of Animal Science, 62 (6), 1719-1731.

Constable, P. D., Walker, P. G., Morin, D. E., & Foreman, J. H. (1998). Clinical and laboratory assessment of hydration status of neonatal calves with diarrhea. Journal of the American Veterinary Medical Association, 212 (7), 991-996.

Cooper, C. A., Evans, A. C., Cook, S., & Rawlings, N. C. (1995). Cortisol, progesterone and β-endorphin response to stress in calves. Canadian Journal of Animal Science, 75 (2), 197-201.

Cózar, A., Rodriguez, A. I., Garijo, O., Calvo, L., & Vergara, H. (2016). Effect of space allowance during transport and fasting or non-fasting during lairage on welfare indicators in Merino lambs. Spanish Journal of Agricultural Research, 14 (1), e0501.

Cramer, M. C., & Stanton, A. L. (2015). Associations between health status and the probability of approaching a novel object or stationary human in preweaned group-housed dairy calves. Journal of Dairy Science, 98 (10), 7298-7308.

Crookshank, H. R., Elissalde, M. H., White, R. G., Clanton, D. C., & Smalley, H. E. (1979). Effect of transportation and handling of calves upon blood serum composition. Journal of Animal Science, 48 (3), 430-435.

Cucuzza, L., Riondato, R., Macchi, E., Bellino, C., Franco, G., Biolatti, B., et al. (2014). Haematological and physiological responses of Piemontese beef cattle to different housing conditions. Research in Veterinary Science, 97 (2), 464-469.

Dalmau, A., Temple, D., Rodriguez, P., Llonch, P., & Velarde, A. (2009). Application of the Welfare Quality® protocol at pig slaughterhouses. Animal Welfare, 18 (4) , 497-505.

de la Fuente, J., Sánchez, M., Pérez, C., Lauzurica, S., Vieira, C., de Chávarri, E. G., et al. (2010). Physiological response and carcass and meat quality of suckling lambs in relation to transport time and stocking density during transport by road. Animal, 4 (2), 250-258.

de Passillé, A. M., Rushen, J., & Martin, F. (1995). Interpreting the behaviour of calves in an open-field test: a factor analysis. Applied Animal Behaviour Science, 45 (3-4), 201-213.

de Wilt, J. G. (1985). Behaviour and welfare of veal calves in relation to husbandry systems (Doctoral dissertation). Wageningen, The Netherlands: Agricultural University.

Dellmeier, G., Friend, T., & Gbur, E. (1990). Effects of changing housing on open-field behavior of calves. Applied Animal Behaviour Science, 26 (3), 215-230.

Diesch, T. J. (2002). Welfare and performance of newborn and young dairy calves: a thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Physiology at Massey University' Palmerston North, New Zealand: Massey University.

Diesch, T. J., Mellor, D. J., Stafford, K. J., & Ward, R. N. (2004). Blood metabolites and body temperature of single calves between 1 and 4 days of age in a dairy herd in New Zealand. New Zealand Veterinary Journal, 52 (5), 256-260.

Duve, L. R., Weary, D. M., Halekoh, U., & Jensen, M. B. (2012). The effects of social contact and milk allowance on responses to handling, play, and social behaviour in young dairy calves. Journal of Dairy Science, 95 (11), 6571-6581.

Earley, B., & O'Riordan, E. G. (2006). Effects of transporting bulls at different space allowances on physiological, haematological and immunological responses to a 12-h journey by road. Irish Journal of Agricultural and Food Research, 45 (1), 39-50.

Earley, B., Fisher, A. D., & O'Riordan, E. G. (2006). Effects of pre-transport fasting on the physiological responses of young cattle to 8-hour road transport. Irish Journal of Agricultural and Food Research, 45 (1), 51-60.

Earley, B., Murray, M., Prendiville, D. J., Pintado, B., Borque, C., & Canali, E. (2012). The effect of transport by road and sea on physiology, immunity and behaviour of beef cattle. Research in Veterinary Science, 92 (3), 531-541.

Early, B., & Murray, M. (2010). he effect of road and sea transport on inflammatory, adrenocortical, metabolic and behavioural responses of weanling heifers. BMC Veterinary Research, 6 (1), 36-48.

Edwards, S. (2007). Experimental welfare assessment and on-farm application. Animal Welfare 16 (2), 111-115.

Ekpe, E. D., & Christopherson, R. J. (2000). Metabolic and endocrine responses to cold and feed restriction in ruminants. Canadian Journal of Animal Science, 80 (1), 87-95.

Ellingsen, K., Coleman, G. J., Lund, V., & Mejdell, C. M. (2014). Using qualitative behaviour assessment to explore the link between stockperson behaviour and dairy calf behaviour. Applied Animal Behaviour Science, 153, 10-17.

Færevik, G., Jensen, M. B., & Bøe, K. E. (2006). Dairy calves social preferences and the significance of a companion animal during separation from the group. Applied Animal Behaviour Science, 99 (3), 205-221.

Fakoya, F. A. (2011). Who is concerned about animal care and use in developing countries. Proceedings of the 8th World Congress on Alternatives and Animal Use in the Life Sciences (pp. 265-269). Montreal: ALTEX Proceedings.

Fazio, E., Medica, P., Alberghina, D., Cavaleri, S., & Ferlazzo, A. (2005). Effect of long-distance road transport on thyroid and adrenal function and haematocrit values in Limousin cattle: Influence of body weight decrease. Veterinary Research Communications, 29 (8), 713-719.

Fazio, E., Medica, P., Aronica, V., Grasso, L., & Ferlazzo, A. (2008). Circulating β-endorphin, adrenocorticotrophic hormone and cortisol levels of stallions before and after short road transport: stress effect of different distances. Acta Veterinaria Scandinavica, 50 (1), 6.

Fell, L. R., & Shutt, D. A. (1986). Use of salivary cortisol as an indicator of stress due to management practices in sheep and calves. Proceedings of the Australian Society of Animal Production, 16, (pp. 203-206). (Australia).

Fernandez, X., Monin, G., Culioli, J., Legrand, I., & Quilichini, Y. (1996). Effect of duration of feed withdrawal and transportation time on muscle characteristics and quality in Friesian-Holstein calves. Journal of Animal Science, 74 (7), 1576-1583.

Fisher, A. D., Crowe, M. A., O'Kiely, & Enright, W. J. (1997). Growth, behaviour, adrenal and immune responses of finishing beef heifers housed on slatted floors at 1.5, 2.0, 2.5 or 3.0 m^2 space allowance. Livestock Production Science, 51 (1-3), 245-254.

Fisher, A. D., Stevens, B. H., Conley, M. J., Jongman, E. C., Lauber, M. C., Hides, S. J., et al. (2014). The effects of direct and indirect road transport consignment in combination with feed withdrawal in young dairy calves. Journal of Dairy Research, 81 (3), 297-303.

Fraser, D. (2008). Understanding Animal Welfare: The Science in its Cultural Context. Oxford, England, UK, pp 324: Wiley-Blackwell.

Fregonesi, J. A., & Leaver, J. D. (2001). Behaviour, performance and health indicators of welfare for dairy cows housed in strawyard or cubicle systems. Livestock production science, 68 (2), 205-216.

Fröhli, D., & Blum, J. W. (1988). Effects of fasting on blood plasma levels, metabolism and metabolic effects of epinephrine and norepinephrine in steers. Acta endocrinologica, 118 (2), 254-259.

Gånheim, C., Alenius, S., & Waller, K. P. (2007). Acute phase proteins as indicators of calf herd health. The Veterinary Journal, 173 (3) , 645-651.

Garner, J. P. (2005). Stereotypies and other abnormal repetitive behaviors: potential impact on validity, reliability, and replicability of scientific outcomes. Ilar Journal, 46 (2), 106-117.

Giannetto, C., Fazio, F., Casella, S., Marafioti, S., Giudice, E., & Piccione, G. (2011). Acute phase protein response during road transportation and lairage at a slaughterhouse in feedlot beef cattle. Journal of Veterinary Medical Science, 73 (11), 1531-1534.

Goldhawk, C., Janzen, E., González, L. A., Crowe, T., Kastellic, J., Pajor, E., et al. (2014). Trailer microclimate and calf welfare during fall-run transportation of beef calves in Alberta. Journal of Animal Science, 92 (11), 5142-5154.

González, L. A., Schwartzkopf-Genswein, K. S., Bryan, M., Silasi, R., & Brown, F. (2012a). Factors affecting body weight loss during commercial long haul transport of cattle in North America. Journal of Animal Science, 90 (10), 3630-3639.

González, L. A., Schwartzkopf-Genswein, K. S., Bryan, M., Silasi, R., & Brown, F. (2012b). Relationships between transport conditions and welfare outcomes during commercial long haul transport of cattle in North America. Journal of Animal Science, 90 (10), 3640-3651.

González-Jimenez, E., & Blaxter, K. L. (1962). The metabolism and thermal regulation of calves in the first month of life. British Journal of Nutrition, 16 (1), 199-212.

Gottardo, F., Mattiello, S., Cozzi, G., Canali, E., Scanziani, E., Ravarotto, L., et al. (2002). The provision of drinking water to veal calves for welfare purposes. Journal of Animal Science, 80 (9), 2362-2372.

Grandin, T. (1998a). Objective scoring of animal handling and stunning practices at slaughter plants. Journal of American Veterinary Medical Association, 212, 36-40.

Grandin, T. (1998b). The feasibility of using vocalization scoring as an indicator of poor welfare during cattle slaughter. Applied Animal Behaviour Science, 56 (2), 121-128.

Grandin, T. (2001). Cattle vocalizations are associated with handling and equipment problems at beef slaughter plants. Applied Animal Behaviour Science, 71 (3) , 191-201.

Grasso, F., Napolitano, F., De Rosa, G., Quarantelli, T., Serpe, L., & Bordi, A. (1999). Effect of pen size on behavioral, endocrine, and immune responses of water buffalo (Bubalus bubalis) calves. Journal of Animal Science, 77 (8), 2039-2046.

Grigor, P. N., Cockram, M. S., Steele, W. B., Le Sueur, C. J., Forsyth, R. E., Guthrie, J. A., et al. (2001). Effects of space allowance during transport and duration of mid-journey lairage period on the physiological, behavioural and immunological responses of young calves during and after transport. Animal Science, 73 (2), 341-360.

Grigor, P. N., Cockram, M. S., Steele, W. B., McIntyre, J., Williams, C. L., Leushuis, I. E., et al. (2004). A comparison of the welfare and meat quality of veal calves slaughtered on the farm with those subjected to transportation and lairage. Livestock Production Science, 91 (3), 219-228.

Groutides, C. P., & Michell, A. R. (1990). Changes in plasma composition in calves surviving or dying from diarrhoea. British Veterinary Journal, 146 (3), 205-210.

Gupta, S., Earley, B., Ting, S. T., & Crowe, M. A. (2005). Effect of repeated regrouping and relocation on the physiological, immunological, and hematological variables and performance of steers. Journal of Animal Science, 83 (8), 1948-1958.

Gupta, S., Early, B., & Crowe, M. A. (2007). Effect of 12-hour road transportation on physiological, immunological and haematological parameters in bulls housed at different space allowances. The Veterinary Journal, 173 (3), 605-616.

Haley, D. B., de Passillé, A. M., & Rushen, J. (2001). Assessing cow comfort: Effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows. Applied Animal Behaviour Science, 71 (2) , 105-117.

Haley, D. B., Rushen, J., & de Passillé, A. M. (2000). Behavioural indicators of cow comfort: activity and resting behaviour of dairy cows in two types of housing. Canadian Journal of Animal Science, 80 (2), 257-263.

Hänninen, L, Hepola, H., Rushen, J., de Passillé, A. M., Pursiainen, P., et al. (2003). Resting behaviour, growth and diarrhoea incidence rate of young dairy calves housed individually or in groups in warm or cold buildings. Acta Agriculturae Scandinavica, Section A — Animal Science, 53 (1), 21-28.

Hänninen, L., de Passillé, A. M., & Rushen, J. (2005). The effect of flooring type and social grouping on the rest and growth of dairy calves. Applied Animal Behaviour Science, 91 (3-4), 193-204.

Hemsworth, P. H., Rice, M., Karlen, M. G., Calleja, L., Barnett, J. L., Nash, J., et al. (2011). Human–animal interactions at abattoirs: Relationships between handling and animal stress in sheep and cattle. Applied Animal Behaviour Science, 135 (1) , 24-33.

Herskin, M. S., Kristensen, A. M., & Munksgaard, L. (2004). Behavioural responses of dairy cows toward novel stimuli presented in the home environment. Applied Animal Behaviour Science, 89 (1) , 27-40.

Hickson, R. E., Zhang, I. L., & McNaughton, L. R. (2015). Brief communication: Birth weight of calves born to dairy cows in New Zealand. Proceedings of the New Zealand Society of Animal Production (75), 257-259.

Hopster, H., & Blokhuis, H. J. (1994). Validation of a heart-rate monitor for measuring a stress response in dairy cows. Canadian Journal of Animal Science, 74 (3) , 465-474.

Howard, P. (2004). Investigation of calf health and welfare on dairy farms in south-west England. The Veterinary Record, 155 (9), 262-265.

Hudson, S., Mullord, M., Whittlestone, W. G., & Payne, E. (1976). Plasma corticoid levels in healthy and diarrhoeic calves from birth to 20 days of age. British Veterinary Journal, 132 (6), 551-556.

Hultgren, J., Wiberg, S., Berg, C., Cvek, K., & Kolstrup, C. L. (2014). Cattle behaviours and stockperson actions related to impaired animal welfare at Swedish slaughter plants. Applied Animal Behaviour Science, 152, 23-37.

Huxley, J. N., Main, D. C., Whay, H. R., Burke, J., & Roderick, S. (2004). Animal welfare assessment benchmarking as a tool for health and welfare planning in organic dairy herds. Veterinary Records, 155, 237-239.

Ibáñez, M., De la Fuente, J., Thos, J., & de Chavarri, E. G. (2002). Behavioural and physiological responses of suckling lambs to transport and lairage. Animal Welfare, 11 (2), 223-230.

Ishiwata, T., Uetake, K., Kilgour, R. J., Ehuchi, Y., & Tanaka, T. (2008). Comparison of time budget of behaviors between penned and ranged young cattle focused on general and oral behaviors. Animal Science Journal, 79 (4), 518-525.

Ishizaki, H., & Kariya, Y. (2010). Road transportation stress promptly increases bovine peripheral blood absolute NK cell counts and cortisol levels. Journal of Veterinary Medical Science, 72 (6), 747-753.

Jacobson, L. H., & Cook, C. J. (1998). Partitioning psychological and physical sources of transport related stress in young cattle. The Veterinary Journal, 155 (2), 205-208.

Jacor, S. K., Ramnath, V., Philomina, P. T., Rahunandhanan, K. V., & Kannan, A. (2001). Assessment of physiological stress in periparturient cows and neonatal calves. Indian Journal of Physiology and Pharmacology, 45 (2), 233-238.

Jago, J. G., Krohn, C. C., & Matthews, L. R. (1999). The influence of feeding and handling on the development of the human–animal interactions in young cattle. Applied Animal Behaviour Science, 62 (2), 137-151.

Jarvis, A. M., Messer, C. D., & Cockram, M. S. (1996). Handling, bruising and dehydration of cattle at the time of slaughter. Animal Welfare, 5 (3), 259-270.

Jarvis, A. M., Selkirk, L., & Cockram, M. S. (1995). The influence of source, sex class and pre-slaughter handling on the bruising of cattle at two slaughterhouses. Livestock Production Science, 43 (3), 215-224.

Jasper, J., Budzynska, M., & Weary, D. M. (2008). Weaning distress in dairy calves: Acute behavioural responses by limit-fed calves. Applied Animal Behaviour Science, 110 (1), 136-143.

Jensen, M. B. (1999). Effects of confinement on rebounds of locomotor behaviour of calves and heifers, and the spatial preferences of calves. . Applied Animal Behaviour Science, 62 (1) , 43-56.

Jensen, M. B. (2001). A note on the effect of isolation during testing and length of previous confinement on locomotor behaviour during open-field test in dairy calves. Applied Animal Behaviour Science, 70 (4), 309-315.

Jensen, M. B., & Kyhn, R. (2000). Play behaviour in group-housed dairy calves, the effect of space allowance. Applied Animal Behaviour Science, 67 (1) , 35-46.

Jensen, M. B., Vestergaard, K. S., Krohn, C. C., & Munksgaard, L. (1997). Effect of single versus group housing and space allowance on responses of calves during open-field tests. Applied Animal Behaviour Science, 54 (2-3) , 109-121.

Jensen, M. B., Vestergaard, K. S., & Krohn, C. C. (1998). Play behaviour in dairy calves kept in pens: the effect of social contact and space allowance. Applied Animal Behaviour Science, 56 (2), 97-108.

Johnston, J. D., & Buckland, R. B. (1976). Response of male Holstein calves from seven sires to four management stresses as measured by plasma corticoid levels. Canadian Journal of Animal Science, 56 (4), 727-732.

Jongman, E. C., & Butler, K. L. (2014). The effect of age, stocking density and flooring during transport on welfare of young dairy calves in Australia. Animals, 4 (2), 184-199.

Kelley, K. W., Osborne, C. A., Evermann, J. F., Parish, S. M., & Hinrichs, D. J. (1981). Whole blood leukocyte vs. separated mononuclear cell blastogenesis in calves: time-dependent changes after shipping. Canadian Journal of Comparative Medicine, 45 (3), 249-258.

Kenny, F. J., & Tarrant, P. V. (1987). The physiological and behavioural responses of crossbred Friesian steers to short-haul transport by road. Livestock Production Science, 17, 63-75.

Kent, J. E., & Ewbank, R. (1986a). The effect of road transportation on the blood constituents and behaviour of calves. II. One to three weeks old. British Veterinary Journal, 142 (2), 131-140.

Kent, J. E., & Ewbank, R. (1986b). The effect of road transportation on the blood constituents and behaviour of calves. III. Three months old. British Veterinary Journal, 142 (4), 326-335.

Kertz, A. F., Reutzel, L. F., & Mahoney, J. H. (1984). Ad libitum water intake by neonatal calves and its relationship to calf starter intake, weight gain, feces score, and season. Journal of Dairy Science, 67 (12), 2964-2969.

Kirton, A. H., & Paterson, D. J. (1973). Effects of starvation before slaughter on some body components of bobby calves. New Zealand Journal of Experimental Agriculture, 1 (2), 115-119.

Knowles, T. G., Brown, S. N., Edwards, J. E., Phillips, A. J., & Warriss, P. D. (1999). Effect on young calves of stop during. The Veterinary Record, 144, 687-692.

Knowles, T. G., Warriss, P. D., Brown, S. N., Edwards, J. E., Watkins, P. E., & Phillips, A. J. (1997). Effects on calves less than one month old of feeding or not feeding them during road transport of up to 24 hours. Veterinary Record, 140, 116-124.

Kooijman, J., Wierenga, H. K., & Wiepkema, P. R. (1991). Development of abnormal oral behaviour in group-housed veal calves: effects of roughage supply. In J. H. Metz, & C. M. Groenestein, New Trends in Veal Calves Production. Proc. of Int. Symposium on Veal Calf Production, EEAP Publ. No. 52, 14–16 March 1990 (pp. 54-58). Wageningen, Netherlands: Pudoc, Wageningen.

Krachun, C., Rushen, J., & de Passillé, A. M. (2010). Play behaviour in dairy calves is reduced by weaning and by a low energy intake. Applied Animal Behaviour Science, 122 (2), 71-76.

Lauber, M. C., Hemsworth, P. H., & Barnett, J. L. (2006). The effects of age and experience on behavioural development in dairy calves. Applied Animal Behaviour Science, 99 (1), 41-52.

Lay, D. C., Friend, T. H., Grissom, K. K., Bowers, C. L., & Mal, M. E. (1992). Effects of freeze or hot-iron branding of Angus calves on some physiological and behavioral indicators of stress. Applied Animal Behaviour Science, 33 (2-3), 137-147.

Lensink, B. J., Fernandez, X., Boivin, X., Pradel, P., Le Neindre, P., & Veissier, I. (2000a). The impact of gentle contacts on ease of handling, welfare, and growth of calves and on quality of veal meat. Journal of Animal Science, 78 (5) , 1219-1226.

Lensink, B. J., Boivin, X., Pradel, P., Le Neindre, P., & Veissier, I. (2000b). Reducing veal calves' reactivity to people providing additional human contact. Journal of Animal Science, 78 (5), 1213-1218.

Lensink, B. J., Fernandez, X., Cozzi, G., Florand, L., & Veissier, I. (2001b). The influence of farmers' behavior on calves' reactions to transport and quality of veal meat. Journal of Animal Science, 79 (3) , 642-652.

Lensink, B. J., Raussi, S., Boivin, X., Pyykkönen, M., & Veissier, I. (2001a). Reactions of calves to handling depend on housing condition and previous experience with humans. Applied Animal Behaviour Science, 70 (3), 187-199.

Lensink, B. J., Van Reenen, C. G., Engel, B., Rodenburg, T. B., & Veissier, I. (2003). Repeatability and reliability of an approach test to determine calves' responsiveness to humans: "a brief report". Applied Animal Behaviour Science, 83 (4), 325-330.

Leruste, H., Bokkers, E. A., Heutinck, L. F., Wolthuis-Fillerup, M., van der Werf, J. T., Brscic, M., et al. (2012b). Evaluation of on-farm veal calves' responses to unfamiliar humans and potential influencing factors. Animals, 6 (12), 2003-2010.

Leruste, H., Brscic, M., Coxxi, G., Kemp, B., Wolthuis-Fillerup, M. L., Bokkers, E. A., et al. (2014). Prevalence and potential influencing factors of non-nutritive oral behaviors of veal calves on commercial farms. Journal of Dairy Science, 97 (11), 7021-7030.

Leruste, H., Brscic, M., Heutinck, L. F., Visser, E. K., Wolthuis-Fillerup, M., Bokkers, E. A., et al. (2012a). The relationship between clinical signs of respiratory system disorders and lung lesions at slaughter in veal calves. Preventive Veterinary Medicine, 105 (1), 93-100.

Lidfors, L. M. (1993). Cross-sucking in group-housed dairy calves before and after weaning off milk. Applied Animal Behaviour Science, 38 (1), 15-24.

Llonch, P., King, E. M., Clarke, K. A., Downes, J. M., & Green, L. E. (2015). A systematic review of animal based indicators of sheep welfare on farm, at market and during transport, and qualitative appraisal of their validity and feasibility for use in UK abattoirs. The Veterinary Journal, 206 (3), 289-297.

Locatelli, A., Sartorelli, P., Agnes, F., Bondiolotti, G. P., & Picotti, G. B. (1989). Adrenal response in the calf to repeated simulated transport. British Veterinary Journal, 145 (6), 517-522.

Lürzel, S., Munsch, C., Windschnurer, I., Futschik, A., Palme, R., & Waiblinger, S. (2015a). The influence of gentle interactions on avoidance distance towards humans, weight gain and physiological parameters in group-housed dairy calves. Applied Animal Behaviour Science, 172, 9-16.

Lürzel, S., Windschnurer, I., Futschik, A., Palme, R., & Waiblinger, S. (2015b). Effects of gentle interactions on the relationship with humans and on stress-related parameters in group-housed calves. Animal Welfare, 24 (4), 475-484.

MacKenzie, A. M., Drennan, M., Rowan, T. G., Dixon, J. B., & Carter, S. D. (1997). Effect of transportation and weaning on humoral immune responses of calves. Research in Veterinary Science, 63 (3), 227-230.

Margerison, J. K., Preston, T. R., Berry, N., & Phillips, C. J. (2003). Cross-sucking and other oral behaviours in calves, and their relation to cow suckling and food provision. Applied Animal Behaviour Science, 80 (4), 277-286.

Maria, G., Villarroel, M., Chacon, G., & Gebresenbet, G. (2004). Scoring system for evaluating the stress to cattle of commercial loading and unloading. The Veterinary Record, 154, 818-821.

Marques, R. S., Cooke, R. F., Francisco, C. L., & Bohnert, D. W. (2012). Effects of twenty-four hour transport or twenty-four hour feed and water deprivation on physiologic and performance responses of feeder cattle. Journal of Animal Science, 90 (13), 5040-5046.

Mattiello, S., Canali, E., Ferrante, V., Caniatti, M., Gottardo, F., Cozzi, G., et al. (2002). The provision of solid feeds to veal calves: II. Behavior, physiology, and abomasal damage. Journal of Animal Science, 80 (2), 367-375.

McCausland, I. P., Austin, D. F., & Dougherty, R. (1977). Stifle bruising in bobby calves. New Zealand Veterinary Journal, 25(3), 71-72.

McVeigh, J. M., Tarrant, P. V., & Harrington, M. G. (1982). Behavioral stress and skeletal muscle glycogen metabolism in young bulls. Journal of Animal Science, 54 (4) , 790-795.

Mellor, D. J., & Beausoleil, N. J. (2015). Extending the 'Five Domains' model for animal welfare assessment to incorporate positive welfare states. Animal Welfare, 24 (3), 241-253.

Mellor, D. J., Molony, V., & Robertson, I. S. (1991). Effects of castration on behaviour and plasma cortisol concentrations in young lambs, kids and calves. Research in Veterinary Science, 51 (2), 149-154.

Mellor, D. J., Stafford, K. J., Todd, S. E., Lowe, T. E., Gregory, N. G., Bruce, R. A., et al. (2002). A comparison of catecholamine and cortisol responses of young lambs and calves to painful husbandry procedures. Australian Veterinary Journal, 80 (4), 228-233.

Mellor, D., & Reid, C. (1994). Concepts of animal well-being and predicting the impact of procedures on experimental animals. In R. Baker, G. Jenkin, & D. Mellor, Improving the well-being of animals in the research environment (pp. 3-18). Glen Osmond, Australia : Australian and New Zealand Council for the Care of Animals in Research and Teaching.

Mellor, D., & Webster, J. (2013). Development of animal welfare understanding drives change in minimum welfare standards. Rev Sci Tech Off Int Epiz 33 (1), 1-21.

Miller, K. A., Garner, J. P., & Mench, J. A. (2006). Is fearfulness a trait that can be measured with behavioural tests? A validation of four fear tests for Japanese quail. Animal Behaviour, 71 (6), 1323-1334.

Mintline, E. M., Stewart, M., Rogers, A. R., Cox, N. R., Verkerk, G. A., Stookey, J. M., et al. (2013). Play behavior as an indicator of animal welfare: Disbudding in dairy calves. Applied Animal Behaviour Science, 144 (1), 22-30.

Miranda-de la Lama, G. C., & Mattiello, S. (2010). The importance of social behaviour for goat welfare in livestock farming. Small Ruminant Research, 90 (1), 1-10.

Miranda-de la Lama, G. C., Leyva, I. G., Barreras-Serrano, A., Pérez-Linares, C., Sánchez-López, E., Maria, G. A., et al. (2012). Assessment of cattle welfare at a commercial slaughter plant in the northwest of Mexico. Tropical Animal Health and Production, 44 (3), 497-504.

Mogensen, L., Krohn, C. C., Sørensen, J. T., Hindhede, J., & Nielsen, L. H. (1997). Association between resting behaviour and live weight gain in dairy heifers housed in pens with different space allowance and floor type. Applied Animal Behaviour Science, 55 (1-2), 11-19.

Mohr, E., Langbein, J., & Nürnberg, G. (2002). Heart rate variability: a noninvasive approach to measure stress in calves and cows. Physiology & Behavior, 75 (1), 251-259.

Mollenhorst, H., Rodenburg, T. B., Bokkers, E. A., Koene, P., & De Boer, I. J. (2005). On-farm assessment of laying hen welfare: a comparison of one environment-based and two animal-based methods. Applied Animal Behaviour Science, 90 (3), 277-291.

Molony, V., & Kent, J. E. (1997). Assessment of acute pain in farm animals using behavioral and physiological measurements. Journal of Animal Sciences, 75 (1), 266-272.

Moore, D. A., Atwill, E. R., Kirk, J. H., Brahmbhatt, D., Alonso, L. H., Hou, L., et al. (2003). Prophylactic use of decoquinate for infections with Cryptosporidium parvum in experimentally challenged neonatal calves. Journal of the American Veterinary Medical Association, 223 (6), 839-845.

Morisse, J. P., Huonnic, D., Cotte, J. P., & Martrenchar, A. (2000). The effect of four fibrous feed supplementations on different welfare traits in veal calves. Animal Feed Science and Technology, 84 (1), 129-136.

Mormede, P., Soissons, J., Bluthe, R. M., Raoult, J., Legarff, G., Levieux, D., et al. (1982). Effect of transportation on blood serum composition, disease incidence, and production traits in young calves. Influence of the journey duration. Annales de Recherches Vétérinaires, 13 (4), 369-384.

MPI (Ministry for Primary Industries). (2017, February). Mortality rates in bobby calves 2008 to 2016. Available at: http://www.mpi.govt.nz/law-and-policy/legal-overviews/animal-welfare/animal-welfare-regulations/caring-for-bobby-calves/

MPI (Ministry for Primary Industries). 2015. MPI VS Animal Welfare Procedure for Bobby Calves.

Mülleder, C., Troxler, J., & Waiblinger, S. (2003). Methodological aspects for the assessment of social behaviour and avoidance distance on dairy farms. Animal Welfare, 12 (4) , 579-584.

Munksgaard, L., Ingvartsen, K. L., Pedersen, L. J., & Nielsen, V. K. (1999). Deprivation of lying down affects behaviour and pituitary-adrenal axis responses in young bulls. Acta Agriculturae Scandinavica, Section A-Animal Science, 49 (3), 172-178.

Murata, H. (1989). Suppression of lymphocyte blastogenesis by sera from calves transported by road. . British Veterinary Journal, 145 (3), 257-262.

Murata, H., & Hirose, H. (1990). Impairment of lymphocyte blastogenesis in road-transported calves observed with a whole blood culture technique. Japanese Journal of Veterinary Science, 51 (1), 183-185.

Murata, H., & Hirose, H. (1991). Suppression of bovine lymphocyte and macrophage functions by sera from road-transported calves. British Veterinary Journal, 147 (5), 455-462.

Murata, H., & Miyamoto, T. (1993). Bovine haptoglobin as a possible immunomodulator in the sera of transported calves. British Veterinary Journal, 149 (3) , 277-283.

Murata, H., Takahashi, H., & Matsumoto, H. (1987). The effects of road transportation on peripheral blood lymphocyte subpopulations, lymphocyte blastogenesis and neutrophil function in calves. British Veterinary Journal, 143 (2) , 166-174.

Napolitano, F., Grasso, F., Bordi, A., Tripaldi, C., Saltalamacchia, F., Pacelli, C., et al. (2005). On-farm welfare assessment in dairy cattle and buffaloes: evaluation of some animal-based parameters. Italian Journal of Animal Science, 4 (3), 223-231.

O'Conner, A. M., & Sargeant, J. M. (2014). An introduction to systematic reviews in animal health, animal welfare, and food safety. Animal Health Reviews, 15 (1), 3-13.

Odore, R., D'angelo, A., Badino, P., Bellino, C., Pagliasso, S., & Re, G. (2004). Road transportation affects blood hormone levels and lymphocyte glucocorticoid and β-adrenergic receptor concentrations in calves. The Veterinary Journal, 168 (3), 297-303.

Olsen, D. P., Ritter, R. C., Papasian, C. J., & Gutenberger, S. (1981). Sympathoadrenal and adrenal hormonal responses of newborn calves to hypothermia. Canadian Journal of Comparative Medicine, 45 (3) , 321-326.

Olson, D. P., Papasian, C. J., & Ritter, R. C. (1980). The effects of cold stress on neonatal calves. II. Absorption of colostral immunoglobulins. Canadian Journal of Comparative Medicine, 44 (1), 19-23.

Ortiz-Pelaez, A., Pritchard, D. G., Pfeiffer, D. U., Jones, E., Honeyman, P., & Mawdsley, J. J. (2008). Calf mortality as a welfare indicator on British cattle farms. The Veterinary Journal, 176 (2), 117-181.

Palme, R., Robia, C., Baumgartner, W., & Möstl, E. (2000). Transport stress in cattle as reflected by an increase in faecal cortisol metabolite concentrations. Veterinary Record, 146 (4), 108-109.

Panivivat, R., Kegley, E. B., Pennington, J. A., Kellogg, D. W., & Krumpelman, S. L. (2004). Growth performance and health of dairy calves bedded with different types of materials. Journal of Dairy Science, 87 (11), 3736-3745.

Parker, A. J., Hamlin, G. P., Coleman, C. J., & Fitzpatrick, L. A. (2003). Dehydration in stressed ruminants may be the result of a cortisol-induced diuresis. Journal of Animal Science, 81 (2), 512-519.

Parker, A. J., Hamlin, G. P., Coleman, C. J., & Fitzpatrick, L. A. (2004). Excess cortisol interferes with a principal mechanism of resistance to dehydration in steers. Journal of Animal Science, 82(4), 1037-1045.

Peli, A., Pietra, M., Giacometti, F., Mazzi, A., Scacco, G., Serraino, A., et al. (2016). Survey on animal welfare in nine hundred and forty three Italian dairy farms. Italian Journal of Food Safety, 5 (1), 50-56.

Petherick, J. C., & Phillips, C. J. (2009). Space allowances for confined livestock and their determination from allometric principles. Applied Animal Behaviour Science, 117 (1), 1-12.

Pettiford, S. G., Ferguson, D. M., Lea, J. M., Lee, C., Paull, D. R., Reed, M. T., et al. (2008). Effect of loading practices and 6-hour road transport on the physiological responses of yearling cattle. Australian Journal of Experimental Agriculture, 48 (7), 1028-1033.

Pregel, P., Bollo, E., Cannizzo, F. T., Biolatti, B., Contato, E., & Biolatti, P. G. (2005). Antioxidant capacity as a reliable marker of stress in dairy calves transported by road. Veterinary Record-English Edition, 156 (2), 53.

Prevedello, P., Brščić, M., Schiavon, E., Cozzi, G., & Gottardo, F. (2012). Effects of the provision of large amounts of solid feeds to veal calves on growth and slaughter performance and intravitam and postmortem welfare indicators. Journal of Animal Science, 90 (10) , 3538-3546.

Pritchard, J. C., Burn, C. C., Barr, A. R., & Whay, H. R. (2008). Validity of indicators of dehydration in working horses: A longitudinal study of changes in skin tent duration, mucous membrane dryness and drinking behaviour. Equine Veterinary Journal, 40 (6), 558-564.

Pritchard, J. C., Lindberg, A. C., Main, D. C., & Whay, H. R. (2005). Assessment of the welfare of working horses, mules and donkeys, using health and behaviour parameters. Preventive Veterinary Medicine, 69 (3-4), 265-283.

Raussi, S. (2005). Group management of young dairy cattle in relation to animal behaviour(Doctoral Dissertation). Finland: MMT, Agrifood Research Reports.

Reefmann, N., Kaszàs, F. B., Wechsler, B., & Gygax, L. (2009). Ear and tail postures as indicators of emotional valence in sheep. Applied Animal Behaviour Science, 118 (3), 199-207.

Regula, G., Danuser, J., Spycher, B., & Wechsler, B. (2004). Health and welfare of dairy cows in different husbandry systems in Switzerland. Preventive Veterinary Medicine, 66 (1), 247-264.

Riondato, F., D'Angelo, A., Miniscalco, B., Bellino, C., & Guglielmino, R. (2008). Effects of road transportation on lymphocyte subsets in calves. The Veterinary Journal, 175 (3), 364-368.

Rousing, T., Bonde, M., & Sørensen, J. T. (2001). Aggregating welfare indicators into an operational welfare assessment system: a bottom-up approach. Acta Agriculturae Scandinavica, Section A-Animal Science, 51(S30), 53-57.

Rousing, T., Ibsen, B., & Sørensen, J. T. (2005). A note on: on-farm testing of the behavioural response of group-housed calves towards humans; test–retest and inter-observer reliability and effect of familiarity of test person. Applied Animal Behaviour Science, 94 (3), 237-243.

Rulofson, F. C., Brown, D. E., & Bjur, R. A. (1988). Effect of blood sampling and shipment to slaughter on plasma catecholamine concentrations in bulls. Journal of Animal Science, 66 (5), 1223-1229.

Rushen, J., & de Passillé, A. M. (1995). The motivation of non-nutritive sucking in calves, *Bos taurus*. Animal Behaviour, 49 (6), 1503-1510.

Sandström, V. (2009). Development of a monitoring system for the assessment of cattle welfare in abattoirs. (PhD Dissertation). Uppsala, Sweden. Swedish University of Agricultural Sciences.

Sargent, J. M., & O'Conner, A. M. (2014). Introduction to systematic reviews in animal agriculture and veterinary medicine. Zoonoses and Public Health, 61(S1), 3-9.

Schaefer, A. L., Cook, N. J., Bench, C., Chabot, J. B., Colyn, J., Liu, T., et al. (2012). The non-invasive and automated detection of bovine respiratory disease onset in receiver calves using infrared thermography. Research in Veterinary Science, 93 (2), 928-935.

Schaefer, A. L., Cook, N. J., Church, J. S., Basarab, J., Perry, B., Miller, C., et al. (2007). The use of infrared thermography as an early indicator of bovine respiratory disease complex in calves. Research in Veterinary Science, 83 (3) , 376-384.

Schrader, L., & Todt, D. (1998). Vocal quality is correlated with levels of stress hormones in domestic pigs. Ethology, 104 (10), 859-876.

Schrama, J. W., Arieli, A., Brandsma, H. A., Luiting, P., & Verstegen, M. W. (1993a). Thermal requirements of young calves during standing and lying. Journal of Animal Science, 71 (12), 3285-3292.

Schrama, J. W., Arieli, A., Heetkamp, M. J., & Verstegen, M. W. (1992). Responses of young calves to low ambient temperatures at two levels of feeding. Animal Science, 55 (3) , 397-405.

Schrama, J. W., Arieli, A., Van der Hel, W., & Verstegen, M. W. (1993b). Evidence of increasing thermal requirement in young, unadapted calves during 6 to 11 days of age. Journal of animal science. Journal of Animal Science, 71 (7), 1761-1766.

Schrama, J. W., Heetkamp, M. J., Verstegen, M. W., Shouten, W. G., ven der Veen, F., & Helmond, F. A. (1996). Responses of young calves, on two levels of feeding, to transportation. Animal Science, 63 (1), 79-89.

Schrama, J. W., Roefs, J. P., Gorssen, J., Heetkamp, M. J., & Verstegen, M. W. (1995). Alteration of heat production in young calves in relation to posture. Journal of Animal Science, 73 (8), 2254-2262.

Schwartzkopf-Genswein, K. S., Booth-McLean, M. E., Shah, M. A., Entz, T., Bach, S. J., Mears, G. J., et al. (2007). Effects of pre-haul management and transport duration on beef calf performance and welfare. Applied Animal Behaviour Science, 108 (1), 12-30.

Scott, S. L., & Christopherson, R. J. (1993). The effect of cold adaptation on kinetics of insulin and growth hormone in heifers. Canadian Journal of Animal Science, 73 (1), 33-47.

Sejian, V. (2007). Assessment of Adrenocortical Function. In R. Srivastava, S. Bag, B. Das, & V. Varshney, The Short Course Manual on Clinical Physiology (pp. 138-143). Izatnager: IVRI.

Sejian, V., Lakritz, J., Ezeji, T., & Lal, R. (2011). Assessment methods and indicators of animal welfare. Asian Journal of Animal and Veterinary Advances 6 (4), 301-315.

Smulders, D., Verbeke, G., Mormède, P., & Geers, R. (2006). Validation of a behavioral observation tool to assess pig welfare. Physiology & Behaviour, 89 (3), 438-447.

Stafford, K. J., Mellor, D. J., Todd, S. E., Gregory, N. G., Bruce, R. A., & Ward, R. N. (2001). The physical state and plasma biochemical profile of young calves on arrival at a slaughter plant. New Zealand Veterinary Journal, 49 (4), 142-149.

Stanger, K. J., Ketheesan, N., Parker, A. J., Coleman, C. J., Lazzaroni, S. M., & Fitzpatrick, L. A. (2005). The effect of transportation on the immune status of steers. Journal of Animal Science, 83 (11), 2632-2636.

Stanković, B., Hristov, S., Ostojić-Andrić, D., Zlatanović, Z., Samolovac, L., & Maksimović, N. (2014). The most common health disorders and welfare of dairy cows and calves. Biotechnology in Animal Husbandry, 30 (4), 549-560.

Stephens, D. B., & Toner, J. N. (1975). Husbandry influences on some physiological parameters of emotional responses in calves. Applied Animal Ethology, 1 (3), 233-243.

Stewart, M., Schaefer, A. L., Haley, D. B., Colyn, J., Cook, N. J., Stafford, K. J., et al. (2008). Infrared thermography as a non-invasive method for detecting fear-related responses of cattle to handling procedures. Animal Welfare, 17 (4), 387-393.

Stewart, M., Verkerk, G. A., Stafford, K. J., Schaefer, A. L., & Webster, J. R. (2010). Noninvasive assessment of autonomic activity for evaluation of pain in calves, using surgical castration as a model. Journal of Dairy Science, 93 (8), 3602-3609.

Stewart, M., Webster, J. R., Verkerk, G. A., Schaefer, A. L., Colyn, J. J., & Stafford, K. J. (2007). Non-invasive measurement of stress in dairy cows using infrared thermography. Physiology & Behavior, 92 (3) , 520-525.

Stockman, C. A., Collins, T., Barnes, A. L., Miller, D., Wickham, S. L., Beatty, D. T., et al. (2011). Qualitative behavioural assessment and quantitative physiological measurement of cattle naïve and habituated to road transport. Animal Production Science, 51 (3), 240-249.

Stockman, C. A., Collins, T., Barnes, A. L., Miller, D., Wickham, S. L., Beatty, D. T., et al. (2013). Flooring and driving conditions during road transport influence the behavioural expression of cattle. Applied Animal Behaviour Science, 143 (1), 18-30.

Stockman, C. A., McGilchrist, P., Collins, T., Barnes, A. L., Miller, D., Wickham, S. L., et al. (2012). Qualitative Behavioural Assessment of Angus steers during pre-slaughter handling and relationship with temperament and physiological responses. Applied Animal Behaviour Science, 142 (3), 125-133.

Stull, C. L., & McDonough, S. P. (1994). Multidisciplinary approach to evaluating welfare of veal calves in commercial facilities. Journal of Animal Science, 72 (9), 2518-2524.

Svensson, C., Liberg, P., & Hultgren, J. (2007). Evaluating the efficacy of serum haptoglobin concentration as an indicator of respiratory-tract disease in dairy calves. The Veterinary Journal, 174 (2), 288-294.

Tadich, N., Gallo, C., Brito, M. L., & Broom, D. M. (2009). Effects of weaning and 48 h transport by road and ferry on some blood indicators of welfare in lambs. Livestock Science, 121 (1), 132-136.

Tadich, N., Gallo, C., Bustamante, H., Schwerter, M., & Van Schaik, G. (2005). Effects of transport and lairage time on some blood constituents of Friesian-cross steers in Chile. Livestock Production Science, 93 (3), 223-233.

Takáčová, J., Korim, P., Takac, L., Korimová, J., Malova, J., Michalov, L., et al. (2012). The Welfare Assessment of Calves in Terms of the European Union Legislation. Journal of Life Sciences, 6 (11), 1299-1305.

Tapkı, İ., Şahin, A., & Önal, A. G. (2006). Effect of space allowance on behaviour of newborn milk-fed dairy calves. Applied Animal Behaviour Science, 99 (1), 12-20.

Tarrant, P. V., Kenny, F. J., & Harrington, D. (1988). The effect of stocking density during 4 hour transport to slaughter on behaviour, blood constituents and carcass bruising in Friesian steers. Meat Science, 24 (3), 209-222.

Tarrant, P. V., Kenny, F. J., Harrington, D., & Murphy, M. (1992). Long distance transportation of steers to slaughter: effect of stocking density on physiology, behaviour and carcass quality. Livestock Production Science, 30 (3), 223-238.

Thomas, G. W., & Jordaan, P. (2013). Pre-slaughter mortality and post-slaughter wastage in bobby veal calves at a slaughter premises in New Zealand. New Zealand Veterinary Journal, 61 (3), 127-137.

Todd, S. E. (1998). The effects of fasting and transport on calves : a thesis presented in partial fulfilment of the requirements for the degree of Master of Science at Massey University. Palmerston North, New Zealand: Massey University.

Todd, S. E., Mellor, D. J., Stafford, K. J., Gregory, N. G., Bruce, R. A., & Ward, R. N. (2000). Effects of food withdrawal and transport on five to ten-day-old calves. Research in Veterinary Science, 68, 125-134.

Tosi, M., Canali, E., Gregoretti, L., Ferrante, V., Rusconi, C., Verga, M., et al. (2001). A descriptive analysis of welfare indicators measured on Italian dairy farms: preliminary results. Acta Agriculturae Scandinavica 30, 69-72.

Uetake, K., Ishiwata, T., Tanaka, T., & Sato, S. (2009). Physiological responses of young cross-bred calves immediately after long-haul road transportation and after one week of habituation. Animal Science Journal, 80 (6), 705-708.

Uetake, K., Tanaka, T., & Sata, S. (2011). Effects of haul distance and stocking density on young suckling calves transported in Japan. Animal Science Journal, 82 (4), 587-590.

Van De Water, G., Heylen, T., Swinnen, K., & Geers, R. (2003a). The impact of vertical vibrations on the welfare of calves. Deutsche tierarztliche Wochenschrift, 110 (3), 111-114.

Van de Water, G., Verjans, F., & Geers, R. (2003b). The effect of short distance transport under commercial conditions on the physiology of slaughter calves; pH and colour profiles of veal. Livestock Production Science, 82 (2), 171-179.

Van Reenen, C. G., Engel, B., Ruis-Heutinck, L. F., Van der Werf, J. T., Buist, W. G., Jones, R. B., et al. (2004). Behavioural reactivity of heifer calves in potentially alarming test situations: a multivariate and correlational analysis. Applied Animal Behaviour Science, 85 (1), 11-30.

Van Reenen, C. G., O'Connell, N. E., Van der Werf, J. T., Korte, S. M., Hopster, H., Jones, R. B., et al. (2005). Responses of calves to acute stress: individual consistency and relations between behavioral and physiological measures. Physiology & Behavior, 85 (5), 557-570.

Večerek, V., Šímová, V., Malena, M., & Voslářová, E. (2006). Effect of calf diseases on mortality during transport for slaughter. Acta Veterinaria Brno, 75 (4), 625-630.

Veissier, I., & Le Neindre, P. (1988). Cortisol responses to physical and pharmacological stimuli in heifers. Reproduction Nutrition Développement, 28 (3A) , 553-562.

Veissier, I., Boissy, A., de Passillé, A. M., Rushen, J., Van Reenen, C. G., Roussel, S., et al. (2001). Calves' responses to repeated social regrouping and relocation. Journal of Animal Science, 79 (10), 2580-2593.

Veissier, I., Chazal, P., Pradel, P., & Le Neindre, P. (1997). Providing social contacts and objects for nibbling moderates reactivity and oral behaviors in veal calves. Journal of Animal Science, 75 (2), 356-365.

Veissier, I., Le Neindre, P., & Trillat, G. (1989). The use of circadian behaviour to measure adaptation of calves to changes in their environment. Applied Animal Behaviour Science, 22 (1), 1-12.

Veissier, I., Ramirez de la Fe, A. R., & Pradelc, P. (1998). Nonnutritive oral activities and stress responses of veal calves in relation to feeding and housing conditions. Applied Animal Behaviour Science, 57 (1-2), 35-49.

Vermorel, M., Dardillat, C., Bernet, J., Saido, C., & Demigné, C. (1983). Energy metabolism and thermoregulation in the newborn calf. Annales de Recherches Veterinaires, 14 (4), 382-389.

Vermorel, M., Vernet, J., Dardillat, C., Saido, Demigne, C., & Bavicco, M. (1989). Energy metabolism and thermoregulation in the newborn calf; effect of calving conditions. Canadian Journal of Animal Science, 69 (1), 113-122.

Waiblinger, S., & Menke, C. (2003). Influence of sample size and experimenter on reliability of measures of avoidance distance in dairy cows. Animal Welfare, 12 (4) , 585-589.

Waiblinger, S., Menke, C., Korff, J., & Bucher, A. (2004). Previous handling and gentle interactions affect behaviour and heart rate of dairy cows during a veterinary procedure. Applied Animal Behaviour Science, 85 (1), 31-42.

Warris, P. D., Brown, S. N., Adams, S. J., & Corlett, I. K. (1994). Relationships between subjective and objective assessments of stress at slaughter and meat quality in pigs. . Meat science, 38 (2) , 329-340.

Watts, J. M., & Stookey, J. M. (2000). Vocal behaviour in cattle: the animal's commentary on its biological processes and welfare. Applied Animal Behaviour Science, 67 (1), 15-33.

Webb, L. E., Bokkers, E. A., Engel, B., Gerrits, W. J., Berends, H., & Van Reenan, C. G. (2012). Behaviour and welfare of veal calves fed different amounts of solid feed supplemented to a milk replacer ration adjusted for similar growth. Applied Animal Behaviour Science, 136 (2), 108-116.

Webster, A. J., Gordon, J. G., & McGregor, R. (1978). The cold tolerance of beef and dairy type calves in the first weeks of life. Animal Science, 26 (1) , 85-92.

Webster, A. J., Saville, C., Church, B. M., Gnanasakthy, A., & Moss, R. (1985). Some effects of different rearing systems on health, cleanliness and injury in calves. British Veterinary Journal, 141 (5) , 472-483.

Webster, J. R., Stewart, M., Rogers, A. R., & Verkerk, G. A. (2008). Assessment of welfare from physiological and behavioural responses of New Zealand dairy cows exposed to cold and wet conditions. Animal Welfare, 17 (1), 19-26.

Wemelsfelder, F., Hunter, E. A., Mendl, M. T., & Lawrence, A. B. (2000). The spontaneous qualitative assessment of behavioural expressions in pigs: first explorations of a novel methodology for integrative animal welfare measurement. Applied Animal Behaviour Science, 67 (3) , 193-215.

Wernicki, A., Urban-Chmiel, R., Kankofer, M., Mikucki, P., Puchalski, A., & Tokarzewski, S. (2006). Evaluation of plasma cortisol and TBARS levels in calves after short-term transportation. Revue de médecine vétérinaire, 157 (1), 30-34.

Weschenfelder, A. V., Torrey, S., Devillers, N., Crowe, T., Bassols, A., Saco, Y., et al. (2012). Effects of trailer design on animal welfare parameters and carcass and meat quality of three Pietrain crosses being transported over a long distance. Journal of Animal Science, 90 (9), 3220-3231.

Wesselink, E. (1998). Aspects of the survival and welfare of neonatal calves: a thesis presented in partial fulfillment of the requirements for the degree of Master of Science at Massey University. Palmerston North, New Zealand: Massey University.

Westerath, H. S., Laister, S., Winckler, C., & Knierim, U. (2009). Exploration as an indicator of good welfare in beef bulls: An attempt to develop a test for on-farm assessment. Applied Animal Behaviour Science, 116 (2), 126-133.

White, B. J., Blasi, D., Vogel, L. C., & Epp, M. (2009). Associations of beef calf wellness and body weight gain with internal location in a truck during transportation. Journal of Animal Science, 87 (12), 4143-4150.

Wickham, S. L., Collins, T., Barnes, A. L., Miller, D. W., Beatty, D. T., Stockman, C. A., et al. (2015). Validating the use of qualitative behavioral assessment as a measure of the welfare of sheep during transport. Journal of Applied Animal Welfare Science, 18 (3), 269-286.

Wiepkema, P. R., Van Hellemond, K. K., Roessingh, P., & Romberg, H. (1987). Behaviour and abomasal damage in individual veal calves. Applied Animal Behaviour Science, 18 (3-4), 257-268.

Willett, L. B., & Erb, R. E. (1972). Short term changes in plasma corticoids in dairy cattle. Journal of animal science, 34 (1), 103-111.

Winckler, C., & Willen, S. (2001). The reliability and repeatability of a lameness scoring system for use as an indicator of welfare in dairy cattle. Acta Agriculturae Scandinavica, Section A-Animal Science, 51(30), 103-107.

Windschnurer, I., Schmied, C., Boivin, X., & Waiblinger, S. (2008). Reliability and inter-test relationship of tests for on-farm assessment of dairy cows' relationship to humans. Applied Animal Behaviour Science, 114 (1), 37-53.

Xiccato, G., Trocino, A., Queaque, P. I., Sartori, A., & Carazzolo, A. (2002). Rearing veal calves with respect to animal welfare: effects of group housing and solid feed supplementation on growth performance and meat quality. Livestock Production Science, 75 (3), 269-280.

Zähner, M., Schrader, L., Hauser, R., Keck, M., Langhans, W., & Wechsler, B. (2004). The influence of climatic conditions on physiological and behavioural parameters in dairy cows kept in open stables. Animal Science, 78 (1) , 139-147.

2.2 Observational study of calves in lairage

Materials and Methods

The Massey University Animal Ethics Committee approved all procedures for this study (Protocol 16/56). Observations of calves in lairage were made at 12 different meat processing plants across New Zealand over an 18 week period from June to October 2016. Observations were made at a particular plant during the week that the researchers were in the region for the case-control study. Six of the plants were visited more than once over this period (Table 9). The number of pens observed at each plant varied depending on the number of consignments that had arrived that day and the plant's slaughter schedule (Table 11).

Bobby calves were initially assessed as groups in pens at lairage. The number of calves observed in the pens at the group level varied according to the sizes of the consignments that had arrived at the plant that day. All observations were carried out by a single investigator who had past experience working with dairy calves. Observations were collected using recording forms as presented in Appendix16 (group level observations) and Appendix 17 (individual level observations).

Group level observations

The first part of the study involved observations of groups of calves in lairage. Pens to be observed were randomly selected but the animals must have been in lairage for at least one hour before the start of observation, which often dictated the order in which the pens were observed. The observations and measurements described below were made systematically.

Time in lairage was determined using the arrival time until the start of observations from records provided at the meat processing plants and noting the time that observations of that particular pen of animals started. The week of the study was a continuous variable and was the week in which the observations were made for a particular meat processing plan, with Week 1 being the week beginning June 27th. This represents time in the spring calving season but is roughly a proxy for the time in season (e.g. early in season: week 1-6, middle of season: week 7-12, end of season: week 13-18).

Table 11 Schedule of visits to processing plants over the 18 week period in 2016 along with the number of pens sampled on each visit.

Plant ID number	Region	Date visited	Pens sampled
25	Bay of Plenty	28/06/2016	2
28	Waikato	5/07/2016	6
28	Waikato	6/07/2016	2
6	Taranaki	12/07/2016	3
6	Taranaki	13/07/2016	2
19	Otago	22/07/2016	1
21	Canterbury	25/07/2016	1
22	Canterbury	28/07/2016	2
22	Canterbury	29/07/2016	3
7	Manawatu-Wanganui	1/08/2017	4
25	Bay of Plenty	8/08/2016	6
28	Waikato	15/08/2016	6
23	Hawke's Bay	22/08/2016	7
16	Southland	29/08/2016	6
22	Canterbury	5/09/2016	4
22	Canterbury	6/09/2016	3
7	Manawatu-Wanganui	12/09/2016	6
25	Bay of Plenty	19/09/2016	6
25	Bay of Plenty	26/09/2016	6
23	Hawke's Bay	5/10/2016	7
20	Timaru	10/10/2016	6
10	Tasman	19/10/2016	6
13	Southland	25/10/2016	7

From outside the pen

Observations were first made from outside the pen, without disturbing the animals. Binoculars were used to observe the calves more closely when necessary. The number of calves in the pen was first recorded. The group was then observed for two minutes and the number of animals exhibiting particular behaviours or health indicators was recorded. A full list of the behaviours and health indicators assessed, along with definitions, is provided in Table 12. At the conclusion of the observation period, the outside of the pen was measured using a tape measure so that the stocking density could be determined.

Systematic walk through

After the undisturbed observations were made from outside the pen, a systematic walk through of the pen was completed. The walk through was done in exactly the same way for each pen: the researcher began at one corner and crossed the pen diagonally at a constant pace. The researcher then followed the fence line to the next corner and crossed diagonally the other way before following the fence line to the final corner. If calves were sleeping in the path of the walk through, the researcher walked around the calves while keeping as close as possible to the plan. After the walk through, calves that were still lying were approached directly towards their head to a distance of 0.5 metres and it was noted whether they stood or not.

The number of calves standing was recorded at multiple time points, including:

- Before entering the pen
- Upon pen entry
- During the walk through
- Five minutes after the walk through was completed

Individual level observations

After the group observations were complete, a subsample of five calves from each pen were randomly selected for individual assessment.

Random selection of calves

Random selection of five calves in a pen was achieved as follows. Using a random number table, the researcher would start counting calves (in the same pattern as the systematic walk-through) and the supervisor (from outside the pen) would notify the researcher when the random numbered calf was reached. A strip of duct tape was stuck on the calf’s back to identify it for assessment to be undertaken once all five had been selected. The researcher would then begin counting calves again from that point. The supervisor would use the next random number in the table to notify the researcher when the next random numbered calf was reached, and so on.

Table 12 Description of potential welfare indicators assessed in bobby calves in lairage facilities at 12 meat processing plants across New Zealand during the observational study

Indicator	Description	Level Assessed[1]
Coughing	The rapid and noisy expulsion of air from the lungs. Recorded as either being present or absent.	G & I
Faecal Soiling	The presence of faecal material around the anus, hindquarters and/or hind legs. Recorded as either being present or absent.	G & I
Head Shaking	Repeated rapid movement of the head either side to side, up and down or a combination of both. Recorded as being present or absent	G & I
Head Tilting	Head tilted to one side observed in calves either standing or in sternal recumbency. Recorded as being either present or absent.	G & I
Huddling	The action of calves standing or lying in close proximity of other animals where at least 50% of its body is in contact with another animal. Recorded as being either present or absent	G
Injury	The presence of hairless patches, swellings or lesions. Calves were given an injury score according to Table 13.	G & I
Lying	Position of recumbency while the animals are undisturbed. Noted whether present or absent (standing).	G & I
Nasal Discharge	Discharge from the nostril(s). Noted as: present or absent, unilateral or bilateral, and serous or mucopurulent.	G & I
Ocular Discharge	Discharge from the eye. Noted as: present or absent, unilateral or bilateral, and serous or mucopurulent.	G & I
Oral Behaviours	The expression of non-nutritive oral activities. Noted while the calves are undisturbed as being absent or present. The focus of the behaviour was also recorded as: manipulating an object, cross-sucking or tongue rolling.	G & I
Panting	Noticeably increased respiratory rate (above 36 breaths per minute) with either an open or closed mouth. Noted while the calves are undisturbed as being absent or present	G & I
Play behaviours	The number of animals demonstrating locomotor or social play in the forms of running, bucking, kicking, butting and/or mock fighting. Recorded as being either present or absent.	G & I
Respiratory Rate	Manually count the number of breaths over a 20 second period while the animals are undisturbed.	I
Shivering	Slow and irregular vibration of the body or parts of the body. Noted in undisturbed calves as being present or absent.	G & I
Vocalisation	Utterance recorded as being present or absent. If present in individual calves the frequency and duration were recorded.	G & I
Skin Tent test	Time taken for a pinch on skin taken on the calf's neck to return to the normal position. Noted as a time and then categorised as to whether calves are considered to be dehydrated or not.	I

[1]G = group level observations; I = individual level observations

Table 13 Injury score categories used in the observational study of calves in lairage, as defined by Jørgensen and colleagues (2009)

Score	Description
0	No visual wounds/injuries
1	Hair loss
2	Moderate swelling and/or superficial wound
3	Minor cut through skin or obvious swelling
4	Wound through skin with deeper damage
5	Injury resulting in loss of function

Observations and measurements

Once the five calves were selected, behavioural observations were made, this time from within the pen, but with as little disturbance to the calves as possible. The aim was to observe calves from greater than one metre away, however, the calf's behaviours, posture (lying or standing), the pen stocking density, and behaviours of other calves influenced the distance from which calves were observed. The sex and breed of each calf was noted and it was observed for 2 minutes for the presence of the behaviours and health indicators shown in Table 12.

Skin tent test

The calves were gently positioned with their head up and facing straight ahead. The researcher's right hand was placed with the lateral edge resting lightly against the calf's scapula. A firm pinch of skin was taken between thumb and index finger, cranial to the cranial border of the scapula on the calf's neck. This fold of pinched skin was immediately released. A stop watch was activated at the time of release of the skin fold. Timing was stopped when the skin had returned to the flattened position and was no longer moving. Calves were classified as having moderate dehydration when the skin taking two or more seconds to return to normal after tenting (Constable et al., 1998). Due to contradicting information in the literature, moderate dehydration was also defined as the skin taking three or more seconds to return to normal after tenting (Walker et al*.,* 1998).

Statistical analyses

The outcome of interest in this study was the prevalence of the potential welfare indicators described in Table 12. All statistical analyses were conducted using R version 0.98.932 (R Development Core Team, 2014). The level of significance was set at $P<0.05$.

The data consisted of group level and individual animal data. Variables in the group level data set were recorded as percentage of calves in the pen performing the behaviour. For each prevalent potential welfare indicator, data were non-normally distributed. Therefore, the distributions are summarised using minimum, maximum, median and quartiles.

The individual calf data comprised twelve categorical variables and two continuous variables (respiration rate and skin tent time). Histograms were generated to describe the continuous variables. Skin tent times were collapsed to create a categorical variable ‘moderate dehydration’ with two levels (yes/no). Similarly, respiration rate was collapsed into increased (>36 breaths per minute) or not increased (≤36 breaths per minute). Categorical variables were reported as counts and percentages.

Group or individual outcomes observed at a frequency of 20% or more were analysed further in a two-step process. The first step determined whether an outcome was significantly associated with either time in lairage or week in the study, using the Kruskal-Wallis test. The second step involved construction of a mixed effects logistic regression model to assess the significance of time in lairage and week in study simultaneously, with a random effect added to account for clustering within regions.

Results

One hundred and two (102) group level observations and 504 individual calf observations were made, on a total of 5910 calves across the 12 plants. The median number of calves per pen was 53 (Minimum = 9; Maximum = 172) and the stocking density ranged from 0.21m^2 per animal to 2.72m^2 per animal with a median of 0.44 m^2.

Group level observations

Descriptive statistics for the percentage of calves in a pen engaged a particular behaviour or exhibiting a particular health indicator as observed from outside the pen are provided in Table 14. Lying was the most variable behaviour, with a range of 0–100% (median of 62%). Other prevalent indicators included faecal soiling (range of 1–48%), oral behaviours (0%–47%), vocalising (0–27%) and injuries (0–23%). Other indicators that were less prevalent (<20%) included shivering, ocular discharge, head shaking, nasal discharge and coughing. Panting, huddling & head tilting were not observed in any calves.

The systematic walk-through was completed in all but one pen (n=101) because all of the calves in that pen had been standing before observations commenced. Descriptive statistics for percentage of calves standing before, during and after the walk-through are shown in Table 15. There was variation in the percentage of calves standing before the observer entered the pen (range 0–95%) and little changed when the observer entered the pen. The percentage of calves standing increased when the observer was in the pen (either during the systematic walk through or when approached).

Table 14 Descriptive statistics for percentage of calves exhibiting behavioural and health indicators observed at group level from outside the pen (n=102 pens)

Variable	Minimum	25^{th} Percentile	Median	75^{th} Percentile	Maximum
Number of Calves	9	34	53	79	172
Lying (%)	0	36	62	78	100
Faecal Soiling (%)	1	10	16	24	48
Oral Behaviours (%)	0	7	12	18	47
Vocalising (%)	0	2	5	8	27
Injury (%)	0	0	0	2	23
Shivering (%)	0	0	0	1	17
Ocular Discharge (%)	0	1	3	4	14
Head Shaking (%)	0	0	0	1	8
Nasal Discharge (%)	0	0	1	3	7
Playing (%)	0	0	0	0	4
Coughing (%)	0	0	0	0	2
Head Tilting (%)	0	0	0	0	0
Huddling (%)	0	0	0	0	0
Panting (%)	0	0	0	0	0

Note: Any degree of faecal soiling, injury, or ocular or nasal discharge was counted as the indicator being present

Table 15 Descriptive statistics for percentage of calves in a pen that were observed to be standing before the observer entered the pen, immediately after entry, during a systematic walk through of the pen and five minutes after the walk through.

Stage	Minimum	25th Percentile	Median	75th Percentile	Maximum
Before entry	0	25	37	56	95
Pen entry	0	26	37	56	95
Observer in pen	0	39	54	71	100
5 mins after	0	43	57	74	100

Individual level observations

Sex and breed were recorded for 425 of 504 individual calves. The percentage of females and males was 31.5% (134) and 68.5% (291), respectively. Most calves were considered to be Jersey cross, Kiwi cross or Friesian (Table 16).

Time in lairage before the start of the observation period was recorded for 447 of the 504 calves. The maximum time in lairage was 995 minutes (16.5 hours), the minimum was 60 minutes, and the median was 100 minutes (Figure 3).

Table 16 Breed composition of individual calves observed in lairage

Breed	Number	%
Jersey Cross/Kiwi Cross	193	38.3
Friesian	108	21.4
Beef Cross/Friesian Cross	75	14.9
Jersey	49	9.7
Not recorded	79	15.7
Total	504	100.00

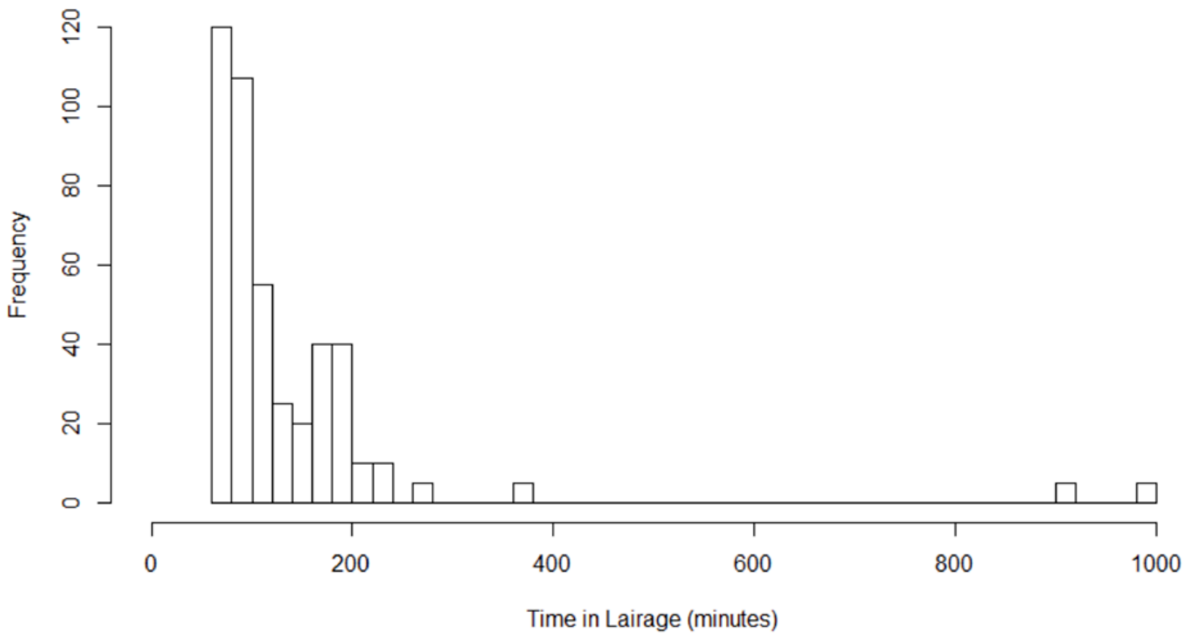

Figure 3 Frequency histogram of time in lairage prior to start of observation period for the 102 pens of calves observed at the group level.

The frequency distribution of skin tent test times is shown in Figure 4. The percentage of calves classified as moderately dehydrated was 63% when moderate dehydration was defined as the skin taking two or more seconds to return to normal after tenting (Constable et al., 1998). This figure dropped to 25% when moderate dehydration was defined as the skin taking three or more seconds to return to normal after tenting (Walker et al., 1998). Ten calves (2%) had skin tent times of 5 seconds or longer.

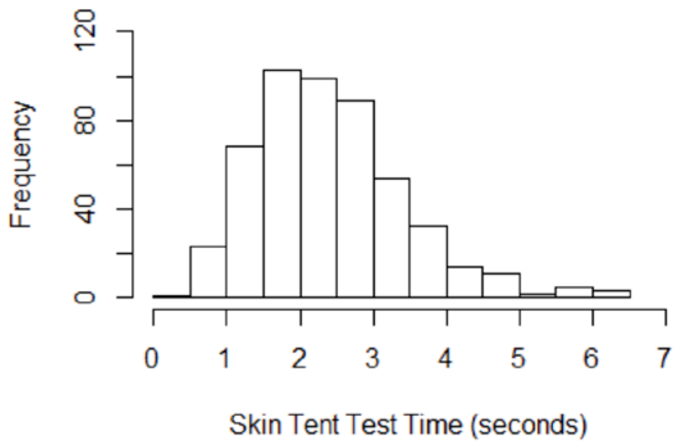

Figure 4 Frequency histogram of skin tent times for 504 individual calves

The prevalence of behavioural and health indicators in the 504 individual calves is shown in Table 17. The most prevalent indicators (observed in >23% of calves) were dehydration, nasal discharge, faecal soiling, nasal discharge, lying, oral behaviours, increased respiration and ocular discharge. Of the 221 calves that had some degree of faecal soiling, 130 (59%) were moderately dehydrated according to the definition used by Constable and co-workers (1998), whereas 56 (25%) were classified as moderately dehydrated according to the definition used by Walker et al. (1998). Two-hundred and five calves (40.7%) had some degree of serous nasal discharge, whilst 116 calves (23%) had some degree of ocular discharge (2 mucopurulent and 114 serous). Of the 193 calves (38.3%) observed lying, 3 were in lateral recumbency and the remainder in sternal recumbency. The three calves observed in lateral recumbency remained in that position for the entire observation period.

Table 17 Number and percentage of calves exhibiting behavioural and health indicators when observed at the individual level (n=504). Any degree of faecal soiling, injury, ocular or nasal discharge was counted as the indicator being present.

Variable	Number	Percentage
Moderately dehydrated[a]	318	63.1
Faecal Soiling	221	43.8
Nasal Discharge	20	40.7
Lying	193	38.3
Oral Behaviours	139	27.6
Moderately dehydrated[b]	125	24.8
Increased Respiration[c]	119	23.6
Ocular Discharge	116	23
Injury	22	4.37
Head Shaking	13	2.6
Shivering	9	1.8
Vocalising	6	1.2
Coughing	0	0
Head Tilting	0	0
Panting	0	0

[a] Moderate dehydration defined as skin taking ≥2 seconds to return to normal after tenting
[b] Moderate dehydration defined as skin taking ≥3 seconds to return to normal after tenting
[c] Increased respiration was defined as respiration rate >36 breaths per minute

Of the 139 calves (27.6%) observed performing oral behaviours, eight were observed manipulating an object and cross-sucking, 122 were manipulating an object only, and 25 were cross-sucking only. Only 22 calves (4.4%) presented with any degree of injury, including hair loss (8 calves), moderate swelling and/or superficial wound (8 calves), minor cut through the skin or obvious swelling (4 calves), or wound through the skin with deeper tissue damage (2 calves). Six calves (1.2%) vocalised during the two-minute observation period. Of these, three vocalised once, one twice, one three times and one four times.

Respiratory rate

Respiratory rate was categorised as decreased if the number of breaths per minute was less than 24, normal if the number of breaths per minute was between 24 and 36 and increased if above 36 breaths per minute (Jackson & Cockcroft, 2002). Of the 504 calves observed, 110 (21.8%) had decreased respiration rates, 275 (54.6%) exhibited normal respiration and 119 (23.6%) had increased respiration rates (Figure 5). It is worth noting that many of those calves classified as having ‘low’ respiratory rates had rates between 20 and 24 breaths per minute, just below the range defined as normal for this study. It may be that the cut-off value of 24 breaths per minute failed to capture the ‘normal ‘ range for the population in this study, thus artificially inflating the percentage of calves with a low respiratory rate.

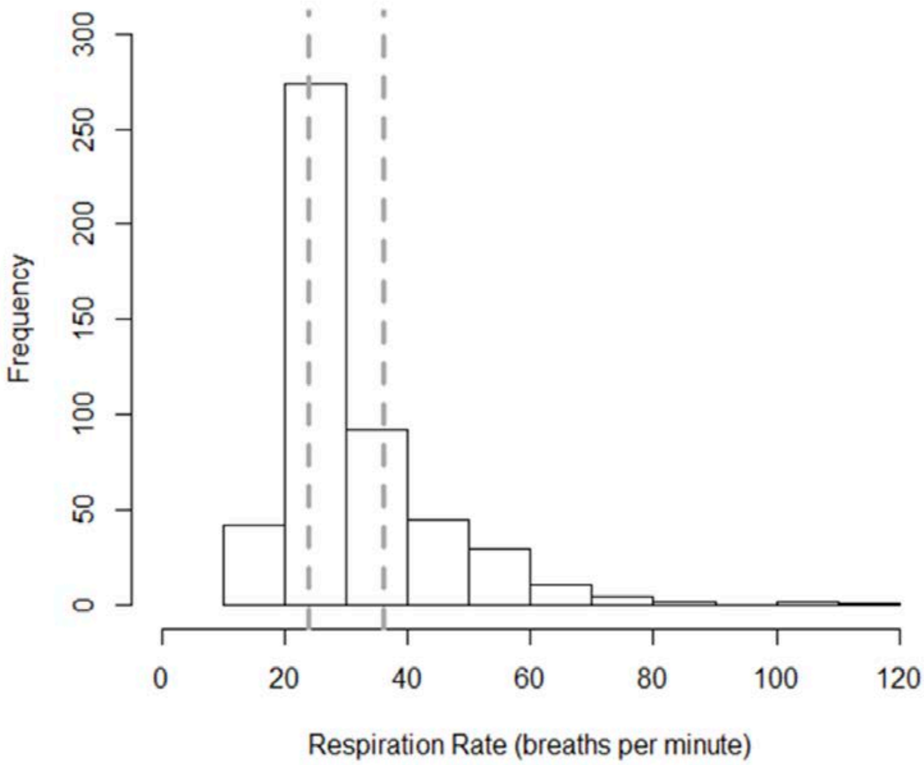

Figure 5 Frequency histogram of respiration rates for 504 individual calves. The normal range is indicated between the dashed lines (24 – 35 breaths per minute).

Impact of time in lairage and time in season on prevalence of potential welfare indicators

The most prevalent indicators identified in the study were dehydration (defined by either 2- or 3-second skin tent return times), faecal soiling, nasal discharge, lying, oral behaviours, increased respiratory rate and ocular discharge. The results of mixed effects logistic regression analyses are presented in Table 18.

Table 18 Results of separate mixed effects logistic regression models exploring the impact of week of study (week) or time in lairage (minutes) on indicators of health and behaviour in bobby calves (n=504) observed in lairage.

Indicator	**Variable**	**Beta**	**SE**	**OR (95%CI)**	**p-value**
Respiratory Rate	Week of study	0	0.2	1.04 (0.71-1.53)	0.84
	Time in lairage	**0**	**0**	**0.10 (0.97-0.99)**	**<0.001**
Ocular Discharge	Week of study	0	0	0.97 (0.92 - 1.03)	0.34
	Time in lairage	0	0	1.00 (1.00-1.00)	0.19
Nasal Discharge	Week of study	**0.3**	**0.1**	**1.31 (1.18-1.46)**	**<0.001**
	Time in lairage	0	0	1.00 (1.00-1.00)	0.37
Faecal Soiling	Week of study	**1.1**	**1.1**	**1.11(1.06-1.17)**	**<0.001**
	Time in lairage	1	1	1.00(1.00-1.00)	0.43
Dehydration (2 sec skin tent)	Week of study	**1.1**	**1**	**1.09 (1.03-1.15)**	**<0.001**
	Time in lairage	0	1	1.00 (1.00-1.00)	0.42
Dehydration (3 sec skin tent)	Week of study	1	1	1.00 (0.95-1.06)	0.92
	Time in lairage	0	1	1.00 (1.00-1.00)	0.06
Oral Behaviours	Week of study	1	0.9	0.96 (0.90-1.03)	0.22
	Time in lairage	0	1	1.00 (1.00-1.00)	0.07
Lying	Week of study	1.1	1	1.07 (1.00-1.15)	0.06
	Time in lairage	**0**	**1**	**1.00 (1.00-1.01)**	**<0.001**

SE = standard error; OR = odds ratio

Discussion

The objective of this study was to determine the prevalence of potential indicators of poor welfare in New Zealand bobby calves in lairage and to evaluate the effects of time in lairage and week of study on the prevalence of potential welfare indicators. A number of health or physiological indicators were found to be prevalent among calves assessed at the individual level. Those with prevalence of 20% or more included: dehydration, faecal soiling, nasal and ocular discharge and increased or decreased respiratory rate. Faecal soiling was also common when calves were assessed from outside the pen at group level. All of these are likely to indicate compromised bobby calf welfare. Prevalent calf behaviours in lairage were lying and oral behaviours; the value of these as indicators of reduced welfare status in this context requires further investigation.

It is important to note that at the time of assessment, many of those calves with the poorest welfare status are likely to have been condemned (on arrival) and thus excluded from the observations. More than 80% of processing plants surveyed in study 1 assessed calves (and condemned where appropriate) within 1 hour of unloading. Because observations were not undertaken until calves had been in lairage for at least one hour in the present study, the majority of COA calves will have been excluded. Thus observations made in lairage do not reflect the complete picture of calf welfare compromise across the supply chain, as condemned calves may have experienced poor welfare prior to arrival at the plant.

Prevalent health or physiological indicators

Moderate dehydration, assessed in individuals using a skin tent test, was prevalent among calves held in lairage at the processing plants visited. Moderate to severe dehydration is often associated with lethargy, weakness and recumbency (Walker et al., 1998) which likely reflect unpleasant experiences for the animal and thus compromised welfare as defined by Mellor and Beausoleil (2015). When dehydration is the result of diarrhoea, as was suggested by the concurrent high prevalence of faecal soiling, those animals would likely experience additional negative experiences such as sickness, abdominal discomfort and perianal pain.

Some caution is required in interpreting the prevalence of dehydration using the skin tent method employed in this study. While this was based on previous studies in neonatal calves, there were some factors that differed. Firstly, other studies used a ‘pinch and twist’ method (e.g. Constable et al., 1998, Walker et al., 1998), whereas we used a pinch only technique. Secondly, the return times defined as reflecting 'moderate' dehydration varied between studies, as did the location at which the test was performed. For example, Walker et al. (1998) defined moderate dehydration as a return time of more than three seconds when testing skin midway along the lateral thorax. In contrast, Constable et al. (1998) defined moderate dehydration as a return time of between two and five seconds when testing skin in the neck location that was used in the current study. Thus, this shorter cut-off time may be more appropriate for determining the prevalence of clinically significant dehydration in the current study. Based on this classification, almost two thirds of the calves assessed in lairage were moderately dehydrated. Although the difference in application of the tent (i.e. pinch versus pinch and twist) might influence return time, the use of pinch alone would be expected to shorten rather than prolong return time, suggesting that, if anything, prevalence may have been underestimated in the present study.

The cause of dehydration in the present study was not determined. There are two plausible hypotheses. Firstly, dehydration could have been the result of diarrhoea. The high prevalence of faecal soiling observed at both the group and individual level in the present study suggests that dehydration may have been associated, at least in part, with scouring. Calf diarrhoea may be attributed to both infectious and nutritional factors (Foster & Smith, 2009; Cho & Yoon, 2014). Nutritional diarrhoea results from a change in feed type, composition or volume and is less common in young calves than infectious diarrhoea which is due to pathogen exposure (Vermunt, 1994; Constable, 2009; Foster & Smith, 2009; Cho & Yoon, 2014). Both aetiologies can result in severe dehydration (Walker et al., 1998). Alternatively, the observed dehydration may have been due to prolonged food/water deprivation. Werner-Omazic et al. (2013) found depriving healthy calves, aged up to 15 days, of food and water for 24 hours resulted in mild dehydration (6% lost body weight). Similarly, food deprivation during transport was found to influence the degree of dehydration in older cattle; mild dehydration (5%) occurred after a 5-hour journey and mild-moderate dehydration (6.5 – 7%) after 10 and 15 hours of travel, respectively (Warriss et al*.,* 1995).

In the present study, it was not known how long ago calves had left the farm of origin, or when they last fed. However, regulations in place at the time of the study specified that calves should be slaughtered within 28 hours of their last feed (MPI, 2011), so the period of food deprivation should have been no more than this. While some plants provide calves with milk replacer in lairage, few record details of food provision and none record the timing and volume ingested by individual calves. Likewise, although water was made available to the calves, whether, when and how much they drank was unknown. Thus, the precise contributing factors to the observed dehydration could not be ascertained. Nonetheless, the high prevalence of clinically significantly dehydration in calves in lairage is consistent with the condemnation and post-mortem findings reported in Study 1.

Ten calves (2%) in the present study had skin tent return times of five seconds or longer. According to Smith (2009), scouring calves with neck skin tent times of five seconds or longer would be severely dehydrated (10–12% bodyweight loss) and comatose. In contrast, calves that were severely dehydrated (14% bodyweight loss) due to induced osmotic diarrhoea were still able to stand and suckle at feeding times, although they preferred to lie the rest of the time (Walker et al. 1998). Therefore, reporting the behaviour and general demeanour of the calves would provide more information on the clinical significance and welfare implications of skin tent test results. This measure was chosen as an indicator of dehydration as it is relatively practical, cheap and easy to perform. However, concurrent evaluation of the calves' general demeanour and degree of enophthalmos (eyeball recession) should be undertaken in future studies to support the findings of the skin tent test in terms of hydration status (Smith, 2009).

There was no significant relationship between time in lairage before the observational period and dehydration using either the 2 or 3 second cut-off. This is in agreement with the findings of Grigor and colleagues (2001) who reported no effect of lairage duration on the occurrence of dehydration. There are, however, two factors that may have influenced this result. Firstly, in the present study there was little variation in the times spent in lairage for individual calves. Although lairage times ranged from 60 to 995 minutes, most were clustered below 200 minutes and the median was 100 minutes (Figure 3). Secondly, the duration of transport and the time since the calf's last feed was unknown. Time in lairage is not indicative of the total time the calf has fasted. Moreover, calves are provided with water in lairage and have the opportunity to rehydrate.

There was a significant relationship between week of study and dehydration (defined using a 2 second cut-off). It is possible this may have been due to an increased incidence of diarrhoea later in the season, or an increase in ambient temperature which could result in heat stress at high stocking densities, especially towards the later part of the season. Further research is required to confirm this.

Nearly a quarter of individual calves exhibited increased respiratory rate. This variable was characterised as closed mouth hyperventilation, rather than open-mouthed panting for thermoregulation. Given that calves were not observed engaging in locomotor playing, this variable likely reflected increased chemical drive to breathe, due to either respiratory or metabolic acidosis Bleul et al., 2007). The absence of coughing makes respiratory infection and impaired gas exchange (i.e. respiratory acidosis) a less likely cause of increased respiratory rate than metabolic acidosis due to scouring. Again, the high prevalence of faecal soiling may support this interpretation.

Logistic regression analysis indicated that the risk of increased respiratory rate decreased with increasing time in lairage. This may have related to physiological stress responses induced by transport and introduction to lairage. Activation of the hypothalamic-pituitary-adrenal axis can result in an increased respiration rate (Fike & Spire, 2006). Calves that spent more time in lairage would have had more time to settle and adapt to their surroundings. More than 20% of calves had a respiratory rate less than 24 breaths per minute (classified as reduced). There is very little evidence suggesting the aetiology of decreased respiratory rate however, it has been linked with painful conditions as well as severe metabolic alkalosis as a precautionary measure to preserve carbon dioxide (Divers & Peek, 2008).

Finally, ocular and nasal discharges were commonly noted in individual calves. While such signs can be indicative of infection, the secretions were clear in all calves. This suggests that the observed ocular and nasal discharge was due to acute irritation, rather than infection. Irritation may have occurred due to dust or noxious gases present during transport or in lairage Nordstrom & McQuitty, 1975; Randall, 1993). Eye irritation, in particular, could be associated with discomfort for the calves. Serous ocular discharge has also been reported to be a clinical sign of disease (McGuirk, 2008). While the aetiology of the discharge cannot be determined from this study, Jorgensen and colleagues (2017) noted a relationship between eye scores (differing severities of ocular discharge) and stocking density on farm, whereby calves in pens with less space were more likely to have more severe eye scores. In the current study, ocular discharge was not associated with either time in lairage or week of study. Conversely, the prevalence of nasal discharge was found to increase with week in the study. Brščić and colleagues (2012) similarly reported that the prevalence of nasal discharge in veal calves increased over time on the farm. The authors identified increased air circulation as a risk factor for nasal discharge. Whether air quality on farm contributed to the increased prevalence of nasal discharge seen later in this study cannot be determined. However, it is of interest to note that none of the dairy farms surveyed in study 1 conducted routine air quality testing in the housing units.

Prevalent behaviours

Care must be taken in the interpretation of behaviours in terms of calf welfare status; prevalence alone does not indicate welfare compromise in calves in lairage. The behaviours assessed in this study were chosen based on a review of the literature, suggesting some relevance to calf welfare.

While oral behaviours were prevalent at both group and individual levels, the meaning of these behaviours for calf welfare in the lairage context is unclear. Manipulation of objects in the pen and sucking on other calves were the most commonly observed oral behaviours; these could indicate hunger, boredom or frustration, all of which are negative experiences which may impact detrimentally on welfare if prolonged or intense (Mellor and Beausoleil, 2015). It is plausible that the calves observed were hungry; however, as it was not known when the calves left the farm (i.e. had access to food), this is only speculative. Alternatively, the oral behaviours observed could be forms of play in calves of this age, although there is no information to support this interpretation currently. The prevalence of oral behaviours was found to decrease over the weeks of the study. There is no information in the literature to explain this observation; however, it may be that plants slaughter more frequently toward the middle of the season such that calves are transported shorter distances and held in lairage for shorter periods, therefore experiencing less hunger.

Lying was highly prevalent both in undisturbed groups of calves and in individuals. Lying itself may not be a useful indicator of welfare status as calves will lie in lairage for various reasons. However, a preference to lie has been associated with severe dehydration in neonatal calves (Walker et al., 1998), and the postural responses of calves to disturbance may be more indicative of their welfare status. Approximately two thirds of the calves were lying down when undisturbed in lairage and most appeared disinclined to stand when a researcher was in the pen, even when approached directly. Almost no calves stood when the researcher entered the pen, less than 10% of those lying stood up when the researcher walked through the pen and only another 10% stood when approached directly towards the head to a distance of 0.5 metres. This suggests either that calves were lethargic or that they did not perceive the researcher as a threat or a source of food. It was not determined whether the 40% of calves that never stood during the group observation period were exhibiting signs of diarrhoea and/or dehydration. In any case, lying alone is probably not a reliable indicator of calf welfare in lairage.

Time in lairage and week of study

Time in lairage is considered to be an influential factor for calf mortality, along with transport duration (O'Grady & Thomas, 2013). During the start and the end of the processing season, the schedules for each meat processing plant can vary considerably, resulting in calves being transported for longer periods to reach an operating plant. This could explain the increase in prevalence of nasal discharge, faecal soiling and moderate dehydration observed in the later weeks of the present study.

Calf mortality also tends to increase towards the end of the season (O'Grady & Thomas, 2013). It is thought this could be due to an accumulation of pathogens in the calf sheds, or due to changes in plant processing schedules in response to a lower throughput of bobby calves later in the season that result in longer transport distances or increased lairage times (O'Grady & Thomas, 2013). In the 2012 bobby calf season, over half of condemnations or pre-slaughter mortalities were linked to infectious diseases, which commonly result in dehydration, acidosis and toxaemia (O'Grady & Thomas, 2013). If unrecognised during ante-mortem inspections, longer lairage periods can increase the frequency of moribund or dead calves (O'Grady & Thomas, 2013).

It must be noted that time in lairage only provides a fraction of the information on the calf's history. As transport time was not traced for the calves in this study, it isn't known how long caves spent on the livestock truck without access to water, or how long since they were last fed. This complicates the interpretation of results.

Methodological considerations

Although a particular welfare indicator may have been considered prevalent, assessment protocols such as the one used in this observational study only provide a snap-shot of welfare status at the time of observation. Most of the potential indicators reflect the welfare state of the animals over a longer period of time than the observational period (Whay et al*.*, 2003).

Likewise, the level at which observations are made can influence the reported prevalence of potential welfare indicators. For example, the prevalence of faecal soiling and expression of oral behaviour at group level (i.e. from outside the pen) were much lower than when assessed on individual calves. Nasal and ocular discharges were rarely noted in groups of calves but were commonly observed in individuals. At group level it was difficult to accurately identify health indicators and assess behaviours from outside the pen and over such a short period. Thus, these discrepancies are probably due to the inability to accurately identify these indicators from outside the pens. They may also reflect differences in the degree to which the indicator was present. For example, any degree of faecal soiling was scored as present for individual calves, but probably only moderate or severe soiling would be visible from outside the pen. Thus, for accurate assessment of indicators of calf health and welfare in lairage, it appears necessary to enter the pen and assess individual calves, but to also make an assessment of the severity and clinical and welfare significance of the sign.

References

Bleul, U. T., Schwantag, S. C., & Kähn, W. K. (2007). Effects of hypertonic sodium bicarbonate solution on electrolyte concentrations and enzyme activities in newborn calves with respiratory and metabolic acidosis. *American journal of veterinary research,* 68 (8), 850-857.

Brščić, M., Leruste, H., Heutinck, L. F., Bokkers, E. A., Wolthuis-Fillerup, M., Stockhofe, N., et al. (2012). Prevalence of respiratory disorders in veal calves and potential risk factors. *Journal of Dairy Science,* 95 (5), 2753-2764.

Cho, Y. I., & Yoon, K. J. (2014). An overview of calf diarrhea-infectious etiology, diagnosis, and intervention. *Journal of Veterinary Science,* 15 (1), 1-17.

Constable, P. D., Walker, P. G., Morin, D. E., & Foreman, J. H. (1998). Clinical and laboratory assessment of hydration status of neonatal calves with diarrhea. *Journal of American Veterinary Medical Association,* 212(7), 991-996.

Cook, A. (2014). The Hunt for the Missing Billion: NZ's Dairy Beef Opportunity. NZ: Kellogg Rural Leaders Programme.

Divers, T. J., & Peek, S. F. (2008). Examination and Assessment. In T. J. Divers, & S. F. Peek, *Rebhun's Diseases of Dairy Cattle* (pp. 3-42). St. Louis, Missouri: Elsevier.

Fike, K., & Spire, M. F. (2006). Transportation of cattle. *Veterinary Clinics: Food Animal Practice,* 22 (2), 305-320.

Foster, D. M., & Smith, G. W. (2009). Pathophysiology of diarrhea in calves. *Veterinary Clinics of North America: Food Animal Practice,* 25 (1), 13-36.

Grigor, P. N., Cockram, M. S., Steele, W. B., Le Sueur, C. J., Forsyth, R. E., Guthrie, J. A., et al. (2001). Effects of space allowance during transport and duration of mid-journey lairage period on the physiological, behavioural and immunological responses of young calves during and after transport. *Animal Science,* 73 (2), 341-360.

Hickson, R. E., Zhang, I. L., & McNaughton, L. R. (2015). Brief communication: Birth weight of dairy calves born to dairy cows in New Zealand. Proceedings of the New Zealand Society of Animal Production, 75, 257-259.

Jackson, P., & Cockcroft, P. (2002). Clinical Examination of Farm Animals. Oxford, UK: Blackwell Science.

McGuirk, S. M. (2008). Disease management of dairy calves and heifers. *Veterinary Clinics of North America: Food Animal Practice,* 24 (1), 139-153.

Mellor, D.J. & Beausoleil, N.J. (2015). Extending the 'Five Domains' model for animal welfare assessment to incorporate positive welfare states. Animal Welfare, 24, 241-253.

MPI (Ministry for Primary Industries). (2017, February). *Mortality rates in bobby calves 2008 to 2016.* Available at: http://www.mpi.govt.nz/law-and-policy/legal-overviews/animal-welfare/animal-welfare-regulations/caring-for-bobby-calves/

MPI (Ministry for Primary Industries) (2011). Code of welfare: Transport within New Zealand. Wellington, NZ: National Animal Welfare Advisory Committee.

Nordstrom, G. A., & McQuitty, J. B. (1975). Response of calves to atmospheric hydrogen sulfide and ammonia. *Proceedings of the Canadian Society of Agriculture and Engineering,* 75, 232.

O'Grady, K., & Thomas, G. (2013). The New Zealand bobby calf welfare project - is it making a difference? *Proceedings of the New Zealand Veterinary Association Conference* (pp. 125-134). VetLearn Foundation.

O'Grady, K., & Wild, R. (2015). Draft report - 2015 Bobby Calf Season. Unpublished MPI report.

Pritchard, J.C., Burn, C.C., Barr, A.R.S., Whay, H.R. 2008. Validity of indicators of dehydration in working horses: A longitudinal study of changes in skin tent duration, mucous membrane dryness and drinking behaviour. Equine Veterinary Journal, 40 (6), 558-564.

Randall, J. M. (1993). Environmental parameters necessary to define comfort for pigs, cattle and sheep in livestock transporters. *Animal Science*, 57 (2), 299-307.

Smith, G. W. (2009). Treatment of Calf Diarrhea: Oral Fluid Therapy. Veterinary Clinics of North America: Food Animal Practice, 25 (1), 55-72.

Stafford, K. J., Mellor, D. J., Todd, S. E., Gregory, N. G., Bruce, R. A., & Ward, R. N. (2001). The physical state and biochemical profile of calves on arrival at a slaughter plant. New

Zealand Veterinary Journal, 49 (4), 142-149.

Vermunt, J. J. (1994). Rearing and management of diarrhoea in calves to weaning. *Australian Veterinary Journal,* 71 (2), 33-41.

Walker, P.G., Constable, P.D., Morin, D.E., Drackely, J.K., Foreman, J.H. & Thurmon, J.C. (1998). A reliable, practical and economical protocol for inducing diarrhea and severe dehydration in the neonatal calf. Canadian Journal of Veterinary Research, 62 (3), 205-213.

Warriss, P. D., Brown, S. N., Knowles, T. G., Kestin, S. C., Edwards, J. E., Dolan, S. K., & Phillips, A. J. (1995). Effects on cattle of transport by road for up to 15 hours. The Veterinary Record, 136(13), 319-323.

Werner-Omazic, A., Tråvén, M., Roos, C., Mellgren, E., & Holtenius, K. (2006). Oral rehydtration with glycerol to dairy calves: Effects on fluid balance, metabolism, and intestinal microbiota. Acta Agriculturae Scandinavica, Section A – Animal Science, 63(1), 47-56.

Wesselink, E. (1998). Aspects of the Survival and Welfare of Neonatal Calves. Massey University, New Zealand.

Whay, H. R., Main, C. J., Green, L. E., & Webster, A. J. (2003). Assessment of the welfare of dairy cattle using animal-based measurements: direct observations and investigation of farm records. *Veterinary Record,* 153, 197-202.

2.3 Conclusions

A systematic review of the published literature identified a total of 99 potential indicators of calf welfare, incorporating nutritional (n=3, Domain 1), environmental, (n=17, Domain 2) health (n=32, Domain 3) and behavioural (n=47, Domain 4) factors. The majority of studies (77%) were experimental. One quarter of studies did not report the location; of those that did the USA, Canada and New Zealand were the most frequently reported, accounting for 22% of all studies. Most studies (86%) were conducted on cows, with a quarter of studies conducted on young animals (<3 weeks of age).

A selection of the potential welfare indicators identified in the systematic review were subsequently applied in an observational study of bobby calves in lairage conducted across several New Zealand processing plants.

The observational study revealed that dehydration, faecal soiling, increased respiratory rate and ocular and/or nasal discharge were highly prevalent among the bobby calves observed. As such, these may be useful physical indicators of aspects of calf welfare. It seems likely that dehydration and faecal soiling reflected calf diarrhoea, although whether this was nutritional or infectious is unknown. Regardless, this may be indicative of reduced welfare among calves in lairage. The progressive development of these indicators from farm collection through to the point of slaughter should be investigated to better understand the welfare status of calves across the supply chain.

Oral behaviours and lying were prevalent behaviours in lairage and may reflect hunger and lethargy/weakness, therefore be proxies for time off feed. However, the links between concurrent physiological or disease status and the expression of these behaviours must be validated before they are used as indicators of calf welfare in this context.

Difficulties in accurately assessing some health/welfare indicators at the group levels may limit their utility in situations where close assessment is not feasible, for example during transport and lairage at higher stocking densities.

General recommendations

It is clear that collecting calves later in a farm's calving season and transporting them for longer increases their risk of mortality. Taken together, the high prevalence of dehydration and faecal soiling observed in individual calves in lairage, the common citation of weakness, recumbency and dehydration as reasons for condemnation and the predominance of diarrhoea and enteritis in the results of post-mortem examination of case calves, suggest that dehydration associated, at least in part, with scouring is a significant risk factor for bobby calf welfare compromise and death. Thus, it is logical to consider the ways in which time in a farm's calving season and travel duration impact on these factors.

Whilst the impact of a slaughter plant's processing schedule on the risk of mortality was not clear in the present study, its identification as a risk factor merits further investigation, given that this is something that could be regulated. In fact, since this research was undertaken the Ministry for Primary Industries have introduced several new regulations governing the management and treatment of bobby calves. These cover, among other things, maximum journey duration and maximum time off feed prior to slaughter (full details are available at: https://www.mpi.govt.nz/dmsdocument/1415-dairy-cattle-animal-welfare-code-of-welfare-2016).

Mortality is currently the only measure of welfare compromise recorded in the bobby calf supply chain. Whilst it is obviously a critical outcome, its low prevalence is a serious impediment to further studies investigating the aetiology of welfare compromise in this context. For this reason an observational study was undertaken to identify other indicators with a higher prevalence that might be useful in assessing the welfare of bobby calves. This study identified seven signs with a prevalence of more than 23% for calves in lairage, and it is interesting that a number of these can be mechanistically related to dehydration, a major reason for condemnation in the case control study. A previous study (Stafford et al. 2001), identified a number of differences between calves deemed 'acceptable' at slaughter and those that were 'marginal'; several of these factors (packed cell volume, urea, lactate and total plasma protein) also share this mechanistic link with dehydration.

The results of the two studies presented here strongly suggest, but do not prove, a causal link between dehydration and mortality. The low prevalence of mortality makes such a link difficult to demonstrate beyond doubt, but if it does exist, then steps to prevent dehydration would be expected to reduce mortality and these preventative measures would be much easier to monitor if reliable indicators of dehydration could be established in bobby calves. Further studies to establish the reliability of the high prevalence indicators in an experimental model of dehydration and to investigate the appearance of these indicators as calves progress through the supply chain would lead to a greater understanding of the aetiology of these measures and of their suitability as proxies for dehydration. This in turn could lead to the development of a validated set of tools for further studies with the aim of reducing dehydration and thereby improving animal welfare with the eventual aim of developing a validated set of regulations to control the welfare of calves across the supply chain.

Appendix 1: Consideration of calf welfare in the decision-making of dairy farmers: A systematic literature review

Abstract

Each day farmers make decisions that have both short and long-term effects on the efficiency, profitability and productivity of the farm. Decisions made on the farm do not always incorporate consideration of the animal welfare implications. Dairy calves represent both the future of the dairy enterprise and another revenue stream either through private or public sales as store cattle or direct sale to the meat processing plant. Decision making is a complex process that encompasses the goals of the farmer, their knowledge of the system and their allocation of resources. The aim of this review was to explore the consideration of animal welfare in dairy farmer decision making specifically relating to calves. A systematic search of the published scientific literature was undertaken using CAB Abstracts, PubMed, Web of Science, Scopus and Google Scholar electronic databases to identify literature on farmer decision making with specific consideration of calf welfare. Decisions were categorised as technical, tactical or strategic. Some evidence was found in the published literature for explicit consideration of calf welfare in dairy farmer decision-making relating to the use of therapeutic medications (analgesics, antibiotics), calving induction, calf health and disease status more generally, and calf value (i.e. market prices). However, the number of published articles reflecting explicit calf welfare consideration was small (14 articles in total). The findings of this review suggest that calf welfare is often a secondary consideration, as labour and financial constraints ensure most of the farmer's time is concentrated on managing the milking herd. A greater understanding of animal welfare consideration in farmer decision-making relating to calf management is needed.

Keywords: animal welfare, farmer decision making

Introduction

The dairy industry is New Zealand's biggest export earner (New Zealand Trade and Enterprise, 2016). To remain competitive in a volatile international market, farmers need to be both efficient and strategic in their use of farm resources. Decisions on how resources are used on the farm can often result in conflict between the production system the farmer aspires to and what is realised. Decision making is the cognitive process of identifying and then selecting a course of action based on the values, goals and objectives of the decision maker (Willock et al., 1999a,b; Edwards-Jones, 2006). Variables that influence farmer behaviour include both person factors such as personality, and external or physical farm factors. The impact that these factors have on behaviour are mediated by the farmer's attitude to farming (e.g. legislation, financial risk, pessimism) and the farming objectives (e.g. success, quality of life, stewardship, succession, diversification) (Willock et al., 1999b).

Intuition also drives farmer decisions. Familiarity with the farm and the knowledge this provides is difficult to quantify or model yet is intrinsic to the decision-making process (Fountas et al., 2006). Utilisation of information also differs amongst farmers. The socio-economic status of the farmer (e.g. age, education level, cognitive ability, dedication) combined with characteristics of the farm and proximity to population centres influences how the farmer accesses information and whether extension services are used (Solano et al., 2003).

Making a decision suggests that there are alternative courses of action available to the decision maker, implying a thorough knowledge of the system and therefore the ability to make rational decisions (Willock et al., 1999a). In many instances decisions are based on learned behaviour passed on from previous generations, even though it may have little or no proven scientific or other knowledge foundation.

Animal welfare is a multi-dimensional concept that encompasses factors such as health and behaviour. The current paradigm in New Zealand, as well as many other countries, is that animals are sentient beings and therefore have feelings, perceptions and experiences that matter to them (Mellor 2015a). Physical dysfunction, impairment or significant disruption to homeostasis can lead to unpleasant mental experiences (Mellor and Beausoleil, 2015). For example, inadequate food or water intake lead to degrees of hunger or thirst, respectively, which can become severely unpleasant and thus significant to welfare if prolonged (Mellor et al. 2009). Likewise, pathophysiological effects of disease may lead to negative experiences such as sickness, breathlessness, lethargy, nausea and pain (Mellor and Beausoleil, 2015).

Animal welfare is an important concern in livestock farming, and farmer decision-making can directly or indirectly result in suboptimal welfare, such as breeding for production or physical traits at the expense of conformation or calving ease (Murray et al., 2002). The five domains model provides a framework for assessing the welfare of calves which encompasses nutritional, environmental, health and behavioural factors and their cumulative impact on the animal's mental experience (Mellor, 2017). Farmer decision making should result in conditions that promote physical/functional states in the first four domains that give rise to a welfare-relevant positive mental state in the fifth domain. The farmer should also intervene, re-evaluating a decision if evidence of poor welfare results. However, to achieve this, the farmer would need to monitor welfare outcomes. Some indicators of welfare include body condition score, disease prevalence and animal behaviour.

Government legislation both limits and in many cases directs the decision making on the farm with regards to animal management. For example, there are government regulations on minimum requirements such as stocking density (space requirements per animal), age and condition acceptable for animal transport (e.g. Anonymous 2016a, b) which do, to an extent, set a certain level of animal welfare.

The incidence of morbidity and mortality of young calves is relatively high across the dairy supply chain (Roy, 1980; Curtis, 1988; Bruning-Fann and Kaneene, 1992; Lance, 1992; Losinger, 1997; Gulliksen, 2009a; Murray and Leslie, 2013; Raboisson, 2013; Thomas and Jordaan, 2013). Factors such as hypothermia, housing, nutrition, handling, transport, dehorning and disease may all be contributing factors (Mellor and Stafford, 2004; Stull et al., 2008). Studies of farmer decision-making around aspects of cattle health, both the promotion of good health and actions to ameliorate poor health of adult cattle and replacement heifers, are well represented in the literature (Webster, 1984; Moss, 1992; Garnsworthy, 2005). However, published literature that makes particular mention of consideration of calf welfare as a specific criterion for farmer decision-making appears to be less prevalent.

This systematic review aimed to explore the specific consideration of animal welfare in dairy farmer decision making relating to calves.

Methods

To assess the published evidence of consideration of calf welfare in the decision-making processes of dairy farmers, a systematic literature search was performed using CAB Abstracts, PubMed, Web of Science, Scopus and Google Scholar electronic databases with no date limits up until May 2016 and restricted to literature available in English. The population was ‘dairy farmers’, the intervention being ‘decision making’ and the outcome was ‘welfare’ in neonatal calves. The key words selected to identify the relevant literature were “farmer decision making” associated with the following “bobby” OR “heifer*” OR “pre-weaned” OR “preweaned” OR “unweaned” OR “neonatal” OR “dairy” OR calf OR “calve*” OR “cattle” OR “youngstock” OR “cow” AND “animal welfare” OR “welfare” OR “ill thrift” OR “thrive” OR “health” OR “maltreatment” OR “mistreatment” OR “treatment”.

All articles identified were exported to the reference management software package EndNote. Duplicate references were removed and abstracts read for relevance. Articles were considered relevant if they referred to the key term “farmer decision making” within a dairy production system. Full text of the relevant articles from both printed and online resources were sourced and articles for which no full text was found were excluded.

All full text articles were then read to identify farmer decision making directly relating to an aspect of neonatal calf rearing. This step was important as bobby calves are most commonly aged between 4 to 7 days when transported from the farm to the slaughter plant. References in the relevant articles were examined to identify any articles that were missed in the electronic database searches and these were subjected to the same inclusion criteria. A summary of the article retrieval process is provided in Figure 1.1.

Articles that were retained for full consideration were categorised as relating to technical, tactical or strategic decisions (Table 1.1). Technical decisions determine resource use and how the production process is run. Tactical decisions impact on the biophysical system through implementation of the production process, while strategic decisions are those that affect or influence the long-term planning or goals of the system (Merot et al., 2008; Fountas et al., 2006).

Results

A total of 162 articles were identified from the initial electronic database searches. After reading abstracts for relevance, 65 articles were retained. Full articles were then read and a further 58 discarded leaving 7 papers for consideration in the review. A further 7 articles were identified through reference checks, resulting in a total of 14 articles that reflected explicit consideration of neonatal calf welfare in the farmer decision-making process. Table 1.1 provides a summary of articles included in the review, categorised by decision type.

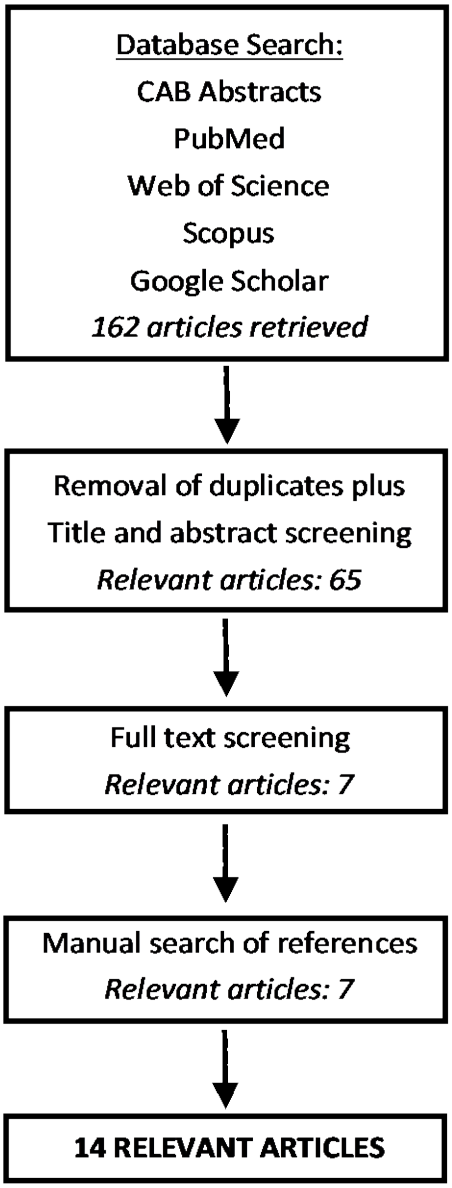

Figure 1.1 Summary of the article retrieval process and results

Table 1.1 Decisions made by farmers that explicitly considered animal welfare

Factors affecting calf welfare	Reference (Author(s) and year of publication)
TECHNICAL DECISIONS	
Use of analgesics for painful procedures	Huxley and Whay, 2007; Gottardo et al., 2011; Hokkanen et al., 2015; Wikman et al., 2013
Use of antibiotics	Jones et al., 2015
Induction	Verkerk et al., 2011; Blackett et al., 2006
TACTICAL DECISIONS	
Calf health	Duval et al., 2016; Solano et al., 2006; Hötzel et al., 2014
Respiratory disease	Duval et al., 2016
Calf mortality	Blackett et al., 2006; Vaarst, 2009: Duval et al., 2016
Health treatments	Crudo et al., 2016
Separation of calf from the dam	Solano et al., 2006
Colostrum management	Wolf et al., 2015
STRATEGIC DECISIONS	
Market prices	Vaarst et al., 2003

Discussion

This review explores specific consideration of calf welfare in dairy farmer decision making reported in the published scientific literature. Studies have shown that animal health and welfare and other non-economic factors may be as important as profitability to dairy farmers when considering different decisions on the farm (Leach et al., 2010; Jones et al., 2015). The consideration of calf welfare in the context of decision-making on dairy farms, as identified in the literature review, is discussed below.

Technical decisions

Information on two forms of technical decision-making was obtained from the literature search. These included decisions surrounding the use of analgesic or antibiotic drugs in dairy calves, and decisions around induction of calving. Four articles were found reporting consideration of analgesic use on welfare grounds but only one reported explicit consideration of antibiotic use for this reason.

The use of analgesics on calves typically relates to the performance of painful husbandry procedures such as dehorning (disbudding), castration and the removal of supplementary teats. Dehorning is common practice in dairy systems for the safety of both farm staff and animals and is known to cause pain-related distress and behavioral changes in calves (Doherty et al., 2007; Stilwell et al., 2009; Stock et al., 2013; Kupczyński et al., 2014). In many countries the use of analgesics for such painful procedures is mandated by government legislation. However, this does not necessarily imply full compliance with the legislation. Farmers' decisions relating to the use of analgesics during painful procedures have been shown to be motivated not only by the cost of the treatment (Huxley and Whay, 2007; Gottardo et al., 201), but also alleviation of pain (Hokkanen et al., 2015). In the study by Hokkanen et al. (2015), the farmer's perception of animal pain influenced their decision to employ a veterinarian and the use of pain relief. In contrast, Gottardo et al. (2011) found that farmers were unwilling to meet the cost of analgesia, despite their belief that disbudding calves caused postoperative pain. Whilst bobby calves are not typically subjected to painful husbandry procedures, these examples serve to illustrate the influence of factors other than animal welfare in decisions surrounding calf management.

Increased antimicrobial use is a concern in all livestock production systems (Food and Agriculture Organization of the United Nations, 2016). The decision by farmers to use antibiotics differs depending on the health condition (Jones et al., 2015). The most common disease conditions for calves during the pre-weaning period are enteritis (scours) and pneumonia (Svennson et al., 2003; Windeyer et al., 2012; Al Mawly et al., 2015). Jones et al. (2015), examining farmers' attitudes towards antimicrobial usage in England and Wales, found that farmers preferentially treated calves with pneumonia. Farmers in this study ranked farm profitability and animal health and welfare as the most important motivators in their decision-making. The risk factors for calfhood diseases are multifactorial and include failure of passive transfer (Aly et al., 2013; Priestley et al., 2013), housing (Gulliksen et al., 2009b; Lorenz et al., 2011) and hygiene (Trotz-Williams et al., 2008). Farmer decisions regarding colostrum management, hygiene and housing would impact on disease incidence and the need for therapeutic intervention as well as the decision to preferentially treat calves. In New Zealand, 86% of antimicrobial use in dairy cattle is directed toward dry cow therapy and mastitis treatment, with only a small proportion directed toward treatment of calf disease (Burgess and French, 2017). Nonetheless, decision-making surrounding the use of antimicrobials in calves is likely subject to similar considerations.

Two articles were found reporting explicit consideration of calf welfare when decisions were made about calving induction. Prior to 2015, induction of late calving cows was routine on some New Zealand dairy farms. The perceived benefit of induced calving in the dairy industry was to tighten up calving patterns, while maintaining the length of the mating season. Following the introduction of a voluntary ban in June 2015, routine non-therapeutic induction of dairy and beef cattle is no longer permitted in New Zealand without veterinary consent and then only under special circumstances. Research has demonstrated that induced calvings of up to 12 weeks resulted in stillborn calves or live calves with decreased vitality (Mansell et al., 2006). While it has been shown that farmers were aware of the detrimental effect of induction on the welfare of the calf, a large percentage still undertook the procedure (Blackett et al., 2006; Verkerk et al., 2011) with the likelihood of high empty rates and culling of cows with high genetic worth overruling calf welfare concerns. However, in the study by Blackett et al. (2006) some farmers chose to induce late in gestation to improve survival of prematurely born calves.

Tactical decisions

Tactical decisions are those most likely to impact on the immediate health of the calf; three articles each reported explicit consideration of animal welfare in tactical decision-making about general calf health and mortality. Farmers can make decisions to address a health and welfare issue in the milking herd that could impact adversely on another part of the system, including calves. For example, in a study by Solano et al (2006), farmers decided to allow extended suckling of the calf from the dam to reduce incidence of mastitis even though some studies have shown increased risk of morbidity and mortality for calves left for an extended period with the dam following calving (Quigley et al., 1994; Weary, 2001).

In a study investigating management practises that affect preweaned calf health and welfare, farmers did not list calf diarrhoea as a herd health concern, despite 71% reporting this as the main cause of calf mortality (Hötzel et al., 2014). Among those surveyed, management decisions were primarily motivated by labour and economic costs, tradition, or cost/benefit to the animal; however, the researchers concluded that there was low interest in or awareness of the repercussion of decisions on calf health and welfare (Solano et al, 2006).

The decision of whether or how to treat sick calves was found to be motivated by farm workers' desire to meet organisational goals, suggesting that management policy has a direct influence on the welfare of neonatal calves (Crudo et al., 2016). In contrast, decisions surrounding identification of sick calves were found to be influenced by an individual's personal belief system, indicating that provision of information alone is insufficient to direct the behaviour of calf care workers (Crudo et al., 2016). Duval et al., 2016 reported that proposed changes to farm management, aimed at reducing disease risk, were not enacted by farmers because they either did not believe the health problem was present on their farm, or felt that it wasn't present at a level that was a cause for concern. Similarly, Blackett et al (2006) reported that the personal values of farm managers were important in decision-making surrounding calving induction. This highlights the fact that, in addition to financial factors, farmer beliefs and experience contribute to the decision-making process.

Strategic decisions

Only one article exploring consideration of calf welfare in strategic decision-making on dairy farms was identified during the literature search and this related to market forces. Market value of a farm output influences decision making as it determines the level of resources that can be allocated. This study suggests that animal welfare considerations in decision-making are being balanced against financial implications. For example, among recently converted organic dairy farmers, decisions relating to disease treatment were driven by animal welfare considerations in acute/severe cases, whereas decisions relating to mild disease were more likely to be financially motivated (Vaarst et al, 2003).

Government legislation also influences decision-making regarding farm practice and management. Low price premiums such as those realised for bobby calves, as well as stricter legislation, such as the New Zealand's Animal Welfare (Calves) Regulations enacted in 2016 and 2017 may influence farmers' decisions on rearing and culling of surplus calves on the farm, thereby potentially impacting animal welfare (Vaarst et al., 2003; Gocsik et al., 2014).

The findings of this review must be interpreted with caution. It is likely that dairy farmers do consider animal welfare in many of their decisions regarding calf and farm management. However, reporting in the scientific literature of the specific factors considered in such decisions is currently rare.

Conclusions

Published scientific research on dairy farmers' consideration of animal welfare in their decision-making is limited. Given the potential for farmer decision-making to influence both calf welfare and farm productivity, there is a need to better understand the various factors influencing decision-making and how animal welfare is weighted among these factors.

References

Al Mawly, J., Grinberg, A., Prattley, D., Moffat, J., Marshall, J., French, N., 2015. Risk factors for neonatal calf diarrhoea and enteropathogen shedding in New Zealand dairy farms. Vet. J. 203, 155-160.

Aly, S. S., Pithua, P., Champagne, J. D., & Haines, D. M. (2013). A randomized controlled trial on preweaning morbidity, growth and mortality in Holstein heifers fed a lacteal-derived colostrum replacer or pooled maternal colostrum. BMC Vet. Res. 9, 168.

Blackett, P., Compton, C., Glassey, C., 2006. To induce or not to induce? Insights into important influences on dairy farmer decision making over induced calving. Proceedings of the New Zealand Society of Animal Production. 66, 350-354.

Bruning-Fann, C., Kaneene, J. B., 1992. Environmental and management risk factors associated with morbidity and mortality in perinatal and pre-weaning calves: a review from an epidemiological perspective. Vet. Bull. 62, 399-413.

Curtis, C.R., Erb, H.N., White, M.E., 1988. Descriptive epidemiology of calfhood morbidity and mortality in New York Holstein herds. Prev. Vet. Med. 5,293–307.

Doherty, T. J., Kattesh, H.G., Adcock, R.J., Welborn, M.G., Saxton, A.M., Morrow, J.L., Dailey, J.W., 2007. Effects of a concentrated lidocaine solution on the acute phase stress response to dehorning in dairy calves. J. Dairy Sci. 90, 4232–4239.

Duval, J.E., Fourichon, C., Madouasse, A., Sjöström, K., Emanuelson, U., Bareille, N., 2016. A participatory approach to design monitoring indicators of production diseases in organic dairy farms. Prev. Vet. Med. 128, 12-22.

Edwards-Jones, G., 2006. Modelling farmer decision making: concepts, progress and challenges. Anim. Sci. 82, 783-790.

Farm Animal Welfare Council., 2009. http://www.fawc.org.uk

Fishbein, M., Ajzen, I., 1975. Belief, attitude, intention and behaviour: An introduction to theory and research. Addison-Wesley, Reading, MA.

Food and Agriculture Organization of the United Nations, 2016 http://www.fao.org/3/a-i6209e.pdf

Fountas, S., Wulfsohn, D., Blackmore, B.S., Jacobsen, H.L., Pedersen, S.M., 2006. A model of decision making and information flows for information-intensive agriculture. Ag. Sys. 87,192-210.

Garnsworthy, P.C. ed. 2005. Calf and heifer rearing: principles of rearing the modern dairy heifer from calf to calving. Nottingham University Press, UK.

Gocsik, É., Saatkamp, H.W., de Lauwere, C.C., Oude Lansink, A.G.J.M., 2014. A conceptual approach for a quantitative economic analysis of farmer's decision making regarding animal welfare. J. Agric. Environ. Ethics. 27, 287-308.

Gottardo, F., Nalon, E., Contiero, B., Normando, S., Dalvit, P., Cozzi., G., 2011. The dehorning of dairy calves: Practices and opinions of 639 farmers. J. Dairy Sci. 94, 5724–5734.

Gulliksen, S.M., Lie, K.I., Løken, T., Østerås, O., 2009a. Calf mortality in Norwegian dairy herds. J. Dairy Sci. 92, 2782-2795.

Gulliksen, S.M., Jor, E., Lie, K.I., Løken, T., Akerstedt, J., Østerås, O., 2009b. Respiratory infections in Norwegian dairy calves. J. Dairy Sci. 92, 5139-5146.

Hokkanen, A.-H., Wilman, I., Korhonen, T., Pastell, M., Valros, A., Vainio, O., Hänninen, L., 2015. Perceptions and practices of Finnish dairy producers on disbudding pain in calves. J. Dairy Sci. 98, 823-831.

Huxley, J.N., Whay, H.R., 2007. Attitudes of UK veterinary surgeons and cattle farmers to pain and the use of analgesics in cattle. Cattle Pract. 15, 189-193.

Jones, P.J., Marier, E.A., Tranter, R.B., Wu, G., Watson, E., Teale, C.J., 2015. Factors affecting dairy farmers' attitudes towards antimicrobial medicine usage in cattle in England and Wales. Prev. Vet. Med. 121: 30-40.

Kupczyński, R., Budny, A., Śpitalniak, K., Tracz, E., 2014. Dehorning of calves – methods of pain and stress alleviation – a review. Ann. Anim. Sci. 14, 231-243.

Lance, S.E., Miller, G.Y., Hancock, D.D., Bartlett, P.C., Heider, L.E., Moeschberger, M.L., 1992. Effects of environment and management on mortality in preweaned dairy calves. J. A. Vet. Med. Assoc. 201, 1197-1202.

Leach, K.A., Whay, H.R., Maggs, C.M., Barker, Z.E., Paul, E.S., Bell, A.K., Main, D.C.J., 2010. Working towards a reduction in cattle lameness: 2. Understanding dairy farmers' motivation. Res. Vet. Sci. 89, 318-323.

Lorenz, I., Earley, B., Gilmore, J., Hogan, I., Kennedy, E., More, S.J., 2011. Calf health from birth to weaning. III. housing and management of calf pneumonia. Irish Vet. J. 64, 14.

Losinger, W.C., Heinrichs, A.J., 1997. Management practices associated with high mortality among preweaned dairy heifers. J. Dairy Res. 64, 1-11.

Mansell, P.D., Cameron, A.R., Taylor, D.P., Malmo, J., 2006. Induction of parturition in dairy cattle and its effects on health and subsequent lactation and reproductive performance. Aust. Vet. J. 84, 312-316.

Mellor, D.J., 2015. Positive animal welfare states and reference standards for welfare assessment. NZ Vet. 63, 17–23.

Mellor, D.J., Beausoleil, N.J., 2015. Extending the Five Domain's model for animal welfare assessment to incorporate positive welfare states. Anim. Welf. 24, 241-253.

Mellor, D.J, Stafford, K.J., 2004. Animal welfare implications of neonatal mortality and morbidity in farm animals. Vet. J. 168, 118-33.

Mellor, D.J., Stafford, K.J., Patterson-Kane, E. 2009. The Sciences of Animal Welfare. Wiley Blackwell, Oxford, Positive animal UK.

Merot, A., Bergez, J.E, Capillon, A., Wery, J., 2008. Analysing farming practices to develop a numerical, operational model of farmer's decision-making processes: An irrigated hay cropping system in France. Ag. Sys. 98,108-118.

Moss, R., 1992. Livestock health and welfare. Longman Scientific and Technical, Harlow, UK.

Murray,R.D., Cartwright, T.A., Downhan, D.Y., Murray, M.A., de Kruif, A., 2002. Comparison of external and internal pelvic measurements of Belgian Blue cattle from sample herds in Belgium and the United Kingdom. Reprod. Dom. Anim., 37, 1-7.

Murray, C.F., Leslie, K.E., 2013. Newborn calf vitality: Risk factors, characteristics, assessment, resulting outcomes and strategies for improvement. Vet. J. 198, 322-328.

New Zealand Trade and Enterprise. 2016. Statistics: Exports – Top 20 Commodities. https://www.nzte.govt.nz/en/invest/statistics/ [accessed May 2016]

Priestley, D., Bittar, J.H., Ibarbia, L., Risco, C.A., Galvão, K.N., 2013. Effect of feeding maternal colostrum or plasma-derived or colostrum-derived colostrum replacer on passive transfer of immunity, health, and performance of preweaning heifer calves. J. Dairy Sci. 96, 3247-3256.

Quigley, J.D., Martin, K.R., Bemis, D.A., Potgieter, L.N.D., Reinemeyer, C.R., Rohrbach, B.W., Dowlen, H.H., Lamar, K.C., 1994. Effects of housing and colostrum feed on the prevalence of selected infectious organisms in faeces of jersey calves. J. Dairy Sci. 77, 3124-3131.

Raboisson, D., Delor, F., Cahuzac, E., Gendre, C., Sans, P., Allaire, G., 2013. Perinatal, neonatal, and rearing period mortality of dairy calves and replacement heifers in France. J. Dairy Sci. 96, 2913-2924

Roy, J., 1980. Factors affecting susceptibility of calves to disease. J. Dairy Sci. 63, 650-664.

Solano, C., León, H., Pérez, E., Herrero, M., 2003. The role of personal information sources on the decision-making process of Costa Rican dairy farmers. Ag. Sys. 76, 3-18.

Stilwell, G., de Carvalho, R.C., Lima, M.S., Broom, D.M., 2009. Effect of caustic paste disbudding, using local anaesthesia with and without analgesia, on behaviour and cortisol of calves. Appl. Anim. Behav. Sci. 116, 35–44.

Stock, M.L., Baldridge, S.L., Griffin, D., Coetzee., J.F., 2013. Bovine dehorning: Assessing pain and providing analgesic management. Vet. Clin. North Am. Food Anim. Pract. 29, 103–133.

Svensson, C., Lundborg, K., Emanuelson, U., Olson, S.-O., 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. Prev. Vet. Med. 58, 179-197.

Thomas, G.W., Jordaan, P., 2013. Pre-slaughter mortality and post-slaughter wastage in bobby veal calves at a slaughter premises in New Zealand. New Zeal. Vet. J. 61, 127-132.

Trotz-Williams, L.A., Martin, S.W., Leslie, K.E., Duffield, T., Nydam, D.V., Peregrine, A.S., 2008. Association between management practices and within-herd prevalence of

Cryptosporidium parvum shedding on dairy farms in southern Ontario. Prev. Vet. Med. 83, 11-23.

Vaarst, M., Sørensen, J.T., 2009. Danish dairy farmers' perceptions and attitudes to calf-management in situations of high versus no calf mortality. Prev. Vet. Med. 89, 128-133.

Verkerk, G., Burke, C., Newman, M., Beukes, P., 2011. Economic impacts of induction reduction strategies. Proceedings of the Society of Dairy Cattle Veterinarians of the NZVA. 7.12.1-7.12.12.

Weary, D. M., 2001. Calf management: improving calf welfare and production. Adv. Dairy Technol. 13, 107-118.

Webster, J., 1984. Calf husbandry, health and welfare. Granada Technical Books, London, UK.

Willock, J., Dreary, I.J., Gibson, G.J., Sutherland, A., Morgan, O., Edwards-Jones, G., McGregor, M.J., Dent, J.B., Grieve, R., 1999a. The role of attitudes and objectives in farmer decision making: business and environmentally orientated behaviour in Scotland. J. Ag. Econ. 50, 286-303.

Willock, J., Dreary, I.J., McGregor, M.J., Sutherland, A., Edwards-Jones, G., Morgan, O., Dent, J.B., Grieve, R., Gibson, G.J., Austin, A., 1999b. Famers' attitudes, objectives, behaviours and personality traits: The Edinburgh study of decision making on farms. J.Voc. Beh. 54, 5-36.

Windeyer, M.C., Leslie, K.E., Godden, S.M., Hodgins, D.C., Lissemore, K.D., LeBlanc, S.J., 2012. The effects of viral vaccination of dairy heifer calves on the incidence of respiratory disease, mortality, and growth. J. Dairy Sci. 95, 6731-6739.

Wolf, R., Barkema, H., De Buck, J., Orsel, K., 2015. Factors affecting management changes on farms participating in a Johne's disease control program. J. Dairy Sci. 98, 7784-7796.

Appendix 2 Summary of articles retrieved in systematic literature review of risk factors for morbidity and mortality in bobby calves

Table 2.1 Risk factors for **mortality** in neonatal calves during rearing on farm

Risk factor	Reference (first author and year of publication)
ENVIRONMENTAL FACTORS	
Type of calf housing	Simensen, 1982; Lance et al., 1992; Razzaque et al., 2009c
Season	Simensen, 1982; Svennson et al., 2006; Brickell et al., 2009; Raboisson et al., 2013; Uetake, 2013; Mellado et al., 2014
Thermic stress	Martin et al., 1975a; Mellado et al., 2014
MANAGEMENT FACTORS	
Colostrum source	Aly et al., 2013; Priestley et al., 2013
Colostrum quality	Armengol, 2016
Calf milk feeding method	Lance et al., 1992
Calf milk feed type	Simensen, 1982; Mansour et al., 2014
Plane of nutrition	Razzaque et al., 2009c
Navel dipping	Lance et al., 1992
Calf treated with antibiotics	Lance et al., 1992
Failure of passive transfer	Simensen, 1982; Razzaque et al., 2009a,c; Windeyer et al., 2012; Priestley et al., 2013; Uetake, 2013; Raboisson et al., 2016
Difficult birth (dystocia)	Arnott et al., 2007; Lombard et al., 2007; Brickell et al., 2009; Gulliksen et al., 2009a; Barrier et al., 2013; Murray et al., 2013; Mellado et al., 2014
Age of dam	Brickell et al., 2009
Parity of dam	Wathes et al., 2008; Brickell et al., 2009
Calf rearer	Simensen, 1982
CALF FACTORS	
Sex of calf	Debnath et al., 1995; Gulliksen et al., 2009a; Megersa et al., 2009; Raboisson et al., 2013; Uetake, 2013; Mansour et al.,

Risk factor	Reference (first author and year of publication)
	2014; Mellado et al., 2014
Breed	Raboisson et al., 2013; Raboisson et al., 2014
Age of calf	Martin et al., 1975b; Waltner-Toewes et al., 1986b; Bruning-Fann, 1992; Debnath et al., 1995; Virtala et al., 1996; Quigley et al., 2006; Wudu et al., 2008; Razzaque et al., 2009ab; Razzaque et al., 2010; Vasseur et al., 2012; Windeyer et al., 2012
Birthweight	Debnath et al., 1995
Twinning	Brickell et al., 2009; Gulliksen et al., 2009a; Mellado et al., 2014
Disease	Simensen, 1982; Waltner-Toewes et al., 1986b; Gitau et al., 1994; Debnath et al., 1995; Sivula et al., 1996; Virtala et al., 1996; Svennson and Liberg, 2006; Morrell et al., 2008; Brickell et al., 2009; Gulliksen et al., 2009a; Razzaque et al., 2009a; Uetake, 2013; Windeyer et al., 2014
MISCELLANEOUS	
Herd size	Simensen, 1982; Lance et al., 1992; Gulliksen et al., 2009a; Mansour, et al., 2014
Farmer education and experience	Mansour et al., 2014

Table 2.2 Risk factors for **morbidity** in neonatal calves during rearing on farm

Risk factors	Reference (first author and year of publication)
ENVIRONMENTAL FACTORS	
Type of calf housing	Bruning-Fann, 1992; Trotz-Williams et al., 2008; Razzaque et al., 2009a; Marcé et al., 2010; Lorenz et al., 2011
Group housing size	Quigley et al., 1994; Losinger, 1997; Weary, 2001; Svennson et al., 2003; Svennson and Liberg, 2006; Lorenz et al., 2011
Housing air quality	Bruning-Fann, 1992; van der Fels-Klerx et al., 2000; Lorenz et al., 2011
Bedding material	Castro-Hermida et al., 2002; Lorenz et al., 2011
Hygiene / cleaning	Trotz-Williams et al., 2008; Wudu et al., 2008
Season	Waltner-Toewes et al., 1986b; Svennson et al., 2003; Trotz-Williams et al., 2007; Windeyer et al., 2014
Thermic stress	Olson et al., 1980; Lorenz et al., 2011; Roland et al., 2016
MANAGEMENT FACTORS	
Colostrum quality	Morin et al., 1997; Svennson et al., 2003; Elizondo-Salazar, 2009; Meganck et al., 2014; Patel et al., 2014; Armengol, 2016
Colostrum source	Franklin et al., 2003; Svennson et al., 2003; Aly et al., 2013; Priestley et al., 2013; Meganck et al., 2014; Patel et al., 2014
Colostrum quantity	Morin et al., 1997; Trotz-Williams et al., 2007; Godden et al., 2009; Furman-Fratczak et al., 2011; Armengol, 2016
Colostrum timing	Wudu et al., 2008
Method of feeding colostrum	Delafosse et al., 1995
Failure of passive transfer	Razzaque et al., 2009c; Windeyer et al., 2012; Aly et al., 2013; Barrier et al., 2013; Priestley et al., 2013; Windeyer et al., 2014; Raboisson et al., 2016
Milk feed quality	Longenbach, 1998; Armengol, 2016
Plane of nutrition	Bruning-Fann, 1992; Trotz-Williams et al., 2008; Beam et al., 2009; Borderas et al., 2009; Khan et al., 2011; Uys et al., 2011; de Pasille et al., 2016
Daily liveweight gain	Murray et al., 2015
Breed	Svennson et al., 2003
Length of time left with dam	Quigley et al., 1994; Weary, 2001
Difficult birth (dystocia)	Lombard et al., 2007; Beam et al., 2009; Furman-Fratczak et al., 2011; Barrier et al., 2013; Murray et al., 2015; Vannucchi et al., 2015

Risk factors	Reference (first author and year of publication)
Calf rearer	Roy, 1980; Al Mawly et al., 2015
Parity of dam	Furman-Fratczak et al., 2011
CALF FACTORS	
Disease	Roy, 1980; Waltner-Toewes et al., 1986ab; Gitau et al., 1994; Sivula et al., 1996; Virtala et al., 1996; Svennson et al., 2003; Singh et al., 2006; Razzaque et al., 2009ac; Razzaque et al., 2010; Windeyer et al., 2014; Al Mawly et al., 2015
Birthweight	Pare et al., 1993
Age of calf	Bruning-Fann, 1992; Delafosse et al., 1995; Virtala et al., 1996; Quigley et al., 2006; Singh et al., 2006; Trotz-Williams et al., 2007; Morrell et al., 2008; Wudu et al., 2008; Megersa et al., 2009; Razzaque et al., 2009a; Razzaque et al., 2010

Table 2.3 Risk factors for **mortality** in neonatal calves during transport

Risk factors	Reference (first author and year of publication)
ENVIRONMENTAL FACTORS	
Calving season / weather	Staples, 1974; Knowles, 1995
MANAGEMENT FACTORS	
Calf handling	Cave et al., 2005
Duration of transport	Cave et al., 2005; Večerek, et al., 2006
CALF FACTORS	
Age of calf	Staples, 1974; Knowles, 1995
Disease	Večerek, et al., 2006

Table 2.4 Risk factors for **morbidity** in neonatal calves during transport

Risk factors	Reference (first author and year of publication)
ENVIRONMENTAL FACTORS	
Stocking density	Jongman et al., 2014
Calving season	Knowles et al., 1999
MANAGEMENT FACTORS	
Lying time	Atkinson, 1992; Knowles et al., 1997; Knowles et al., 1999; Grigor et al., 2001; Fisher et al., 2014
Lying comfort	Uetake et al., 2011; Jongman et al., 2014
Loading and unloading	Kent, 1986
Dehydration	Mormede et al., 1982; Atkinson, 1992; Knowles et al., 1999; Stafford et al., 2001
CALF FACTORS	
Loss of bodyweight	Knowles et al., 1997; Knowles et al., 1999; Fisher et al., 2014; Grigor et al., 2001
Increased serum corticosteroid concentration	Kent, 1986
Increased serum CK concentration	Knowles et al., 1999; Stafford et al., 2001; Fisher et al., 2014; Jongman et al., 2014
Decreased plasma glucose levels	Knowles et al., 1999; Todd et al., 2000; Stafford et al., 2001
Increased cortisol levels	Uetake et al., 2011
Increased noradrenaline levels	Uetake et al., 2011
Increased BHB levels	Stafford et al., 2001
Increased urea concentrations	Stafford et al., 2001
Increased IgM levels	Uetake et al., 2011
Increased AST levels	Uetake et al., 2011
Low GGT	Stafford et al., 2001
Reduced body temperature	Knowles et al., 1999
Increased heart rate	Knowles et al., 1997

Table 2.5 Risk factors for **mortality** in neonatal calves during lairage at the slaughter plant

Risk factors	Reference (first author and year of publication)
MANAGEMENT FACTORS	
Milk in the rumen	Thomas, 2013
Lack of curd in abomasum	
Emaciation	
Non-fatal trauma	
Mild diarrhoea	
CALF FACTORS	
Disease	

Table 2.6 Risk factors for **morbidity** in neonatal calves during lairage at the slaughter plant

Risk factors	Reference (first author and year of publication)
CALF FACTORS	
Increased serum CK concentration	Stafford et al., 2001
Decreased plasma glucose levels	Stafford et al., 2001
Increased BHB levels	Stafford et al., 2001
Loss of bodyweight	Grigor et al., 2001

Appendix 3: Control calf template

Control Calf Details

Plant ID [ ] Control ID [ ] Arrival Date [ ]

Ear Tag Number [ ] Supplier Number [ ]

Supplier Details [ ]

Farm Collection Time [ ] Premises Arrival Time [ ]

Transport Company [ ]

Transport Docket Number [ ]

Transport observations (e.g. wet calves, overcrowding)

[ ]

Sex (please circle)
Male
Female

Breed (please circle)
Jersey
Holstein / Friesian
Dairy Other
Beef Cross

Plant ID [ ] Control ID [ ] Arrival Date [ ]

Ear Tag Number [ ] Supplier Number [ ]

Supplier Details [ ]

Farm Collection Time [ ] Premises Arrival Time [ ]

Transport Company [ ]

Transport Docket Number [ ]

Transport observations (e.g. wet calves, overcrowding)

[ ]

Sex (please circle)
Male
Female

Breed (please circle)
Jersey
Holstein / Friesian
Dairy Other
Beef Cross

Appendix 4: Case calf template

Case Calf Details

Case ID		Arrival Date	
Plant ID		Ear Tag Number	
Supplier Number		Supplier Details	
Farm Collection Time		Premises Arrival Time	
Transport Company			
Transport Docket Number			

Transport observations (e.g. wet calves, overcrowding in truck)

Classification (date and time the calf was classified)

DOA		COA		DIY		CIY	

For COA and CIY calves select reason for condemnation (circle more than one if required. See descriptions for decision on page 3)

Weak	Recumbent	Dehydrated	Deformed
Blind	Injured	Navel defect	Septicaemia
Bulbous heels	Navel Cord	Thin body condition	Other

For COA calves, was the calf able to walk off the truck unaided? (please circle)	Yes	
	No	
For CIY calves, was the calf able to walk unaided in lairage? (please circle)	Yes	
	No	
For condemned calves, was the calf fed in lairage? (please circle). If yes, how much?	Yes	Volume (L)
	No	

Sex (please circle)
Male
Female

Breed (please circle)
Jersey
Holstein / Friesian
Dairy Other
Beef Cross

Autopsy Results (please circle or comment)

General	NSF					
Skin	Lesions:			**Scour**	Moderate	Severe
Umbilicus / Urachus	Wet	Inflam	Other	**Spleen / Lymph nodes**	Inflamed	Reactive
Musculature	Bruising	Other		**Liver**	Inflam	Other
Bones / Joints	Inflam	Fracture	Other	**Urogenital**	Nephritis	Other
Renal / pelvic fat	Depleted	Watery		**Abdomen**	Peritonitis	Other
Cardiopulmonary	Pneumonia - Aspiration / Enzootic					
Abomasum	Inflam	Ulcers	Other			
Abomasal Content	None	Water only		Curd	Grain-Fibre	
Rest of GI	Enteritis	Other				
Other findings						
Conclusions / Diagnosis						

Appendix 5: Descriptors used in post-mortem report for case calves

NSF	No significant findings
Weak	Listless. May require assistance to stand. Can walk but not moving freely.
Recumbent	Unable to/won't walk. Includes calves that may be alert, or calves that are non-alert & largely non responsive.
Dehydrated	Dehydration status is determined by tenting the skin on the neck. If the skin tents, and remains tented (briefly), circle this box.
Deformed	Obvious physical defects e.g. contracted tendons.
Blind	Limited or no vision e.g. either because of an eye defect, or serious eye infection.
Injured	Head, leg or body defect indicative of injury (wounds, fractures).
Navel defect	Navel infection, or navel hernia.
Septicaemia	Depressed, congested mucous membranes, elevated temperature (or sub-normal temperature, when moribund), elevated respiratory and heart rate etc.
Bulbous heels	Hooves that are not firm and worn flat, but are bulbous with soft unworn tissue. This suggests that the calf is less than four days old.
Navel cord	Navel cord is pink or red coloured, raw or fleshy. This suggest that the calf is less than four days old.
Thin body condition	Circle this box if the calf appears thin, ribs and pelvic bones prominent, poor muscling, minimal subcutaneous fat. Includes calves that could be described as poor, emaciated etc.
Other	Record any other significant findings not already listed
Scour	Obvious fluid faecal material around the perineum or direct observation of diarrhoea.
Renal/pelvic fat	Depleted = reduced amounts. Watery = serous atrophy
Abomasal contents	The abomasum will either be completely empty (no food or water) (circle None), or water only, or there will be some food material present. Circle what is present, even if only small quantities.
Cardiopulmonary	Circle Pneumonia if there is a significant area of pneumonia. Plus circle either Aspiration or Enzootic if the location of the lesions suggests the probable cause.

Appendix 6: Script for recruitment of farmers

Researcher from Massey University

My colleague Alana Boulton and I are working on the National Dairy calf project, where we follow randomly selected calves from the meat processing plant back to the farms where they came from.
We are contacting you because one of your calves has been randomly selected from the ______plant in __________.

Hoping you would be willing to take part in a short survey, which will take about half an hour, and is completely confidential, anonymous and has no traceability back to you as the farmer. The survey just gives us an idea about how you rear your calves from birth to collection for the processing plant and the interaction you as the farmer have with the transport company and the processing plant.

Travelling around the country until the end of calving and talking to as many farmers and transport companies as possible and are talking to all the processing plants.

We know this is an extremely busy time of year for you, but were wondering if you had a free moment in which you may be able to talk to us this week. For the study we are travelling around the country 3 times do will only be in the Manawatu this week and we are heading off to the South Island on Sunday for data collection.

The study is completely confidential and other than ourselves there will be no traceability to your input.

Appendix 7: Farm questionnaire

Farm Date ______

Farm Profile

Farm ID ______

Calf ID ______

Farm Postcode ______

1. **Farm type**

Dairy ______ Mixed ______

please specify ______

2. **Enterprise type**

Organic ______ Conventional ______

3. **Operating structure**

Owner/operator ______ Manager ______

Share milker ______

If share milking, record % Owner ______ Share milker ______

Contract milker ______

4. **Calving pattern**

Spring ______ Split calving ______

All year round ______

5. **Predominant breed** ______

Herd details

6. Total number of milking cows (incl. dry cows) at time of visit

______

7. Number of replacements (not including unweaned calves) at time of visit

______

8. Annual replacement rate ______ %

Labour details

9. Number of people involved in the day-to-day care of calves ______

10. Number of people involved in the day-to-day care of bobby calves (if different)

______

	Calves			Bobby Calves	
Male	______	Number of each	Male	______	Number of each
Female	______		Female	______	

11. The number of years the primary calf rearer has spent in livestock farming

______ years

12. The number of years the primary calf rearer has spent rearing bobby calves

______ years

13. Status of primary calf rearer

Family member	
Paid employee	
Full time	
Part time	

14. Number of hours spent per day on duties directly associated with calf rearing

[ ] hours

15. Have there been any significant management/staffing changes since the last calving season?

Yes [ ] No [ ]

If yes, please specify [ ]

16. What training had these staff received in relation to rearing calves?

[ ]

17. In the last 7 days have there been any staff issues in calving that has changed the routine?

[ ]

Pre-calving

18. Do you vaccinate preganant heifers/cows for rotavirus/coronavirus prior to calving?

Yes [ ] No [ ]

Calving management

19. In the last 7 days were did calvings mainly take place? (inside, outside, specific paddock)

[ ]

20. Are calves weighed before being sent to the processing plant? If No, go to Q20.

Yes [ ] No [ ]

21. If yes, what is the average weight (kg)

Male [ ] Female [ ]

22. What is the farm procedure for difficult births? (dystocia, etc.)

[ ]

Separation from the dam / transport to calf shed

23.How long after birth is the calf separated from the dam?

[ ] hours

24. How often are calves collected from the calving area? [ ]

25. How are calves transported from the calving area to the calf rearing facility?

[ ]

26. Describe the weather over the last seven days?

[ ]

Neonatal calf care

27. In the last 7 days, what treatment was applied to neonatal navels following birth?

[ ]

28. How long after birth was the treatment applied? (range) [ ] hours

Colostrum management

29. Is colostrum pooled on the farm?

Yes [ ] No [ ]

30. In the last 7 days, how was the first meal of colostrum to newborn calves managed?

[ ]

31. If colostrum was fed by the calf rearer, what was the quantity of the first feed?

[ ] litres (per calf)

32. Was the first meal of colostrum fed warm or cold? [ ]

33. In the last 7 days, what method was used to feed the first feed of colostrum?

[ ]

34. In the last 7 days was the quality of the colostrum measured? If No, got to Q28

Yes [ ] No [ ]

35. If yes, what method was used to test the quality?

[ ]

36. If calves do not drink sufficient quantity of colostrym during the first 24 hours, is an oesophageal feeder employed?

Yes [ ] No [ ]

37. Is there a different procedure of feeding colostrum for replacements and bobby calves? If No, go to Q31.

Yes [ ] No [ ]

38. If yes, how does the procedure differ?

[ ]

Milk feeding programme

39. Do you have a different feeding programme for the replacement heifers and bobby calves?

Yes [ ] No [ ]

	Replacement heifers	Bobby calves
Type of milk		
Volume of milk per feeding		
Density of DM g/L		
Number of daily feedings		

40. Type of feeding system used

Replacements	
Bobby calves	

41. Is the milk fed warm or cold?

Replacements	
Bobby calves	

42. Is the temperature of the milk checked?

Yes [ ] No [ ]

43. Temperature [ ] ℃

44. Milk details

Crude protein%	
Fat%	
Ash%	
Moisture%	

Water

45. In the last 7 days, at what age after birth were calves given access to water?

[ ] days

46. Description of water in calf pen (trough size, accessibility, cleanliness) if able to view

[ ]

Housing

47. What type of housing is used for replacement heifers?

Individual		Inside	
Group		Outside	
Pens with bars (visual contact allowed)			
Pens with solid walls (no visual contact)			
Wooden or metal cage			

Other (please specify) ______________________

48. What type of housing is used for bobby calves?

Individual		Inside	
Group		Outside	
Pens with bars (visual contact allowed)			
Pens with solid walls (no visual contact)			
Wooden or metal cage			

Other (please specify) ______________________

49. Replacement heifers

Number of calves per housing unit		
Size of housing unit (sqr meters)		
Age entering housing unit		days
Number of days in housing unit		days
Type of bedding used		
How often the bedding is changed		
How often bedding added to the pen		
Bedding changed between calves		Y/N
Frequency of cleaning/disinfection of pen		
Air flow checked in housing area		Y/N

Describe access to outdoor space ______________________

50. Bobby calves

Number of calves per housing unit		
Size of housing unit (sqr meters)		
Age entering housing unit		
Number of days in housing unit		
Type of bedding used		
How often the bedding is changed		
How often bedding added to the pen		
Bedding changed between calves		Y/N
Frequency of cleaning/disinfection of pen		
Air flow checked in housing area		Y/N

Describe access to outdoor space ______________________

Bobby calves

51. In the last 7 days, when were bobby calves separated from replacement calves?

52. In the last 7 days, how were bobby calves selected for transport to the processing plant?

53. In the last 7 days what was the age range of calves sent for processing?

days

54. How did you decide which processor to use this calving season?

55. Were you advised the day prior to collection about the approximate collection time? If No, go to Q51.

Yes No

56. If yes, how often in the last 7 days did the actual time differ more than 2 hours from the approximate time advised by the transport company?

57. What contact did you have from the processor prior to the start of this season?

58. What contact did you have from the transporter prior to the start of this season?

59. In the last 7 days, where were bobby calves housed on the day of collection?

60. In the last 7 days, what time were bobby calves fed on the day of collection?

61. What are the loading facilities on the farm?

62. Is a member of the farm staff present when bobby calves are collected?

Yes No

63. What is the procedure if a bobby calf is rejected by the transport company?

64. Date of first calving 2016 spring season

Appendix 8: Transport questionnaire

Transport

Date

Case ID / Control ID

Supplier Number

Date of collection

Time of Collection

Date of arrival

Time of arrival

Transport Company

Truck Number

Transport docket number

Driver's ID No

---

1. How many transport employees were present in the truck at collection?

2. How many employees were present in the truck at unloading at the plant?

3. Lifter 1 ID No

4. Lifter 2 ID No

5. Truck

Farm collection

Number of decks

Number of pens per deck

Number of calves per pen

Unloading (if a different truck than collection due to transhipping)

Number of decks

Number of pens per deck

Number of calves per pen

6. Total Number of calves in the truck at offloading

7. First farm of the day collection time

8. What was the catchment area of the truck that collected the bobby calves from the farm?

9. What were the weather conditions on the farm during collection of the bobby calves?

10. Did transhipping occur between the farm and processing plant?

Yes

No

If yes, provide details of original truck and driver/lifter details.

11. Transport Company

12. Truck Number

13. Driver's ID No

14. Lifter 1 ID No

15. Lifter 2 ID No

16. Describe the transhipping procedure for calves

17. Were calves from different farms mixed at transhipping?

Yes

No

18. What time did the calves arrive at the transhipping location?

19. How long where they held before continuing the journey to the plant?

20. Time of collection of whole consignment at transhipping

21. What training had the driver received in relation to collection, loading and unloading of bobby calves and animal welfare?

22. What training had the lifter(s) received in relation to collection, loading and unloading of bobby calves and animal welfare?

23. Have there been any significant management changes with regards to the transporting of bobby calves between the 2015 and 2016 spring calving season?

Appendix 9: Processing plant questionnaire

Processing Plant

Date

Plant ID | Enterprise Type

Date the plant started processing bobby calves for the 2016 spring calving season

Arrival at the plant and unloading

1. In the last 7 days, during what hours did calves arrive at the plant?

2. In the last 7 days, how many days did the plant process bobby calves?

days

3. In the last 7 days, during what hours did the plant process bobby calves?

4. In the last 7 days was CCTV operational at the plant during unloading, lairage and processing of bobby calves?

Yes | No

5. In which part of the plant does CCTV record?

6. In the last 7 days, how many trucks carrying bobby calves could be offloaded simultaneously?

7. Is the ramp automated? Yes | No

8. What angle (degrees) is the ramp set at?

9. Is the truck / trailer inspected on arrival at the processing plant? (e.g. condition, approved transporter)

Yes | No

10. In the last 7 days, how many staff were employed to offload bobby calves?

Seasonal | Permanent

11. What training had these staff received in relation to unloading bobby calves and animal welfare?

12. In the last 7 days, did truck drivers assist with the unloading of bobby calves?

Yes [ ] No [ ]

13. Who is responsible for assessing the condition of the bobby calves on arrival at the plant?

[ ]

14. At what point during processing is stock assessment done? (e.g. at offloading, in lairage)

[ ]

15. Are the percentage of wet or scouring calves recorded for each consignment? If No, go to Question 16.

Yes [ ] No [ ]

16. If yes, in the last 7 days what were the percentage of wet calves and scouring calves?

Wet calves % [ ] Scouring calves % [ ]

17. In the last 7 days, what was done with bobby calves that were unable to walk off the transport?

[ ]

18. In the last 7 days, were recovery/sick Nursery pens used? If No, go to Q22.

Yes [ ] No [ ]

19. In the last 7 days, how many bobby calves were kept in a nursery pen?

[ ] Not recorded [ ]

20. If a nursery pen is present, what are the Standard Operating Procedures for caring for bobby calves in the nursery pen? (Feed, water, medicine)

[ ]

Volume of milk fed per calf per feeding [ ] litres

Number of feeds [ ]

Type of milk feed [ ]

Temperature [ ]

Method used for feeding calves [ ]

21. In the last 7 days, what type of flooring was present in the nursery pens?

22. In the last 7 days, who decided if a bobby calf was to be COA?

23. In the last 7 days, how long after unloading was the decision made to euthanize the COA bobby calves? (provide range)

24. In the last 7 days, who was responsible for euthanizing the COA bobby calf?

25. In the last 7 days, what method was employed to euthanize the COA bobby calf?

Lairage

26. In the last 7 days, how many staff were involved in penning bobby calves?

27. In the last 7 days, how were bobby calves moved from offloading to the pens? (e.g. rattle, flappers)

28. What training had these staff received in relation to moving and penning bobby calves and animal welfare?

29. In the last 7 days, describe the water in lairage for bobby calves (trough size, accessibility, cleanliness)

30. In the last 7 days was feed provided in lairage for bobby calves? (please tick). If No, please go to question 35.

Yes ☐ No ☐

31. If yes, under what circumstances?

32. What was the volume of milk fed per calf per feeding? ☐ litres

33. How many feeds did the bobby calves receive? ☐

34. Type of milk feed

35. Was the milk fed warm or cold?

36. What method was used for feeding calves?

37. In the last 7 days, what type of flooring was present in bobby calf lairage?

38. In the last 7 days what were the size of bobby calf holding pens?

m^2

39. In the last 7 days what was the maximum number of bobby calves per pen?

40. In the last 7 days, how long were bobby calves held in lairage before processing? (provide range)

hours

41. In the last 7 days, who decided if a bobby calf was to be condemned in lairage?

42. In the last 7 days, who was responsible for euthanizing the CIY bobby calf?

43. In the last 7 days, what method was employed to euthanize the CIY bobby calf?

44. How many staff are trained in the human slaughter of bobby calves?

45. How are calves moved into the holding pens ready for slaughter? (e.g. rattles, flappers)

Processing

46. In the last 7 days, what hours did the plant process bobby calves? (provide range)

47. In the last 7 days, what was the chain speed used to process bobby calves?

48. In the last 7 days, how many staff were involved in processing bobby calves?

49. What training do the staff processing bobby calves receive?

50. What were the weather conditions at the plant during the last 7 days?

51. Have there been any significant management changes with regards to processing bobby calves between the 2015 and 2016 spring calving seasons?

Figures

Numbers for last 7 days

Number of bobby calves delivered to the plant	
Number of bobby calves DOA	
Number of bobby calves COA	
Number of bobby calves DIY	
Number of bobby calves CIY	

Appendix 10: Farm descriptive statistics

Table 10.1 Distribution of farms surveyed by region

Region	Frequency	Percentage
Auckland	1	0.52
Bay of Plenty	15	7.73
Canterbury	42	21.65
Gisborne	1	0.52
Hawke's Bay	3	1.55
Marlborough	1	0.52
Manawatu-Wanganui	28	14.43
Northland	4	2.06
Otago	17	8.76
Southland	17	8.76
Taranaki	14	7.22
Tasman	2	1.03
Waikato	42	21.65
Wellington	2	1.03
West Coast	5	2.58
Total	194	100.00

Table 10.2 Distribution of farms surveyed by Island

Island	Frequency	Percentage
North	110	56.70
South	84	43.30
Total	194	100.00

Table 10.3 Farm type

Farm type	Frequency	Percentage
Dairy	175	90.21
Mixed	19	9.79
Total	194	100.00

Table 10.4 Enterprise type

Enterprise	Frequency	Percentage
Conventional	193	99.48
Organic	1	0.52
Total	194	100.00

Table 10.5 Operating structure of surveyed farms

Operating structure	Frequency	Percentage
Contractor or manager	36	18.56
Owner	117	60.31
Share milker	41	21.13
Total	194	100.00

Table 10.6 Calving pattern

Calving pattern	Frequency	Percentage
Split	15	7.73
Spring	179	92.27
Total	194	100.00

Table 10.7 Predominant dairy breed on farm

Predominant breed	Frequency	Percentage
Friesian or Friesian cross	105	54.12
Jersey or Jersey cross	22	11.34
Kiwi cross	159	30.41
Other	8	4.12
Total	194	100.00

Table 10.8 Herd size on farm

Minimum	25th percentile	Median	75th percentile	Maximum
120	390	650	905	2500

Table 10.9 Number of replacement heifers on farm at time of survey

Minimum	25th percentile	Median	75th percentile	Maximum
0	80	150	225	750

Table 10.10 Annual replacement rate for the farm (%)

n	Mean	Standard deviation
194	23.8	5.2

Table 10.11 Number of staff caring for calves

Minimum	25th percentile	Median	75th percentile	Maximum
1	1	2	2	6

Table 10.12 Whether there were separate staff caring for bobby calves

Separate bobby carers	Frequency	Percentage
No	177	91.24
Yes	17	8.76
Total	194	100.00

Table 10.13 Number of years the primary calf rearer had spent livestock farming

Minimum	25th percentile	Median	75th percentile	Maximum
1	9	19.5	25	50

Table 10.14 Number of years the primary calf rearer had spent rearing bobby calves

Minimum	25th percentile	Median	75th percentile	Maximum
1	5	10	20	50

Table 10.15 Status of primary calf rearer

Status	Frequency	Percentage
Family member, full time	87	44.85
Family member, part time	22	11.34
Paid, full time	60	30.93
Paid, part time	25	12.89
Total	194	100.00

Table 10.16 Hours per day spent on calf rearing duties

Hours	Frequency	Percentage
≤3 hours	60	30.92
3.5–6 hours	76	39.18
>6 hours	58	29.90
Total	194	100.00

Table 10.17 Whether there were any significant management or staff changes between the 2015/2016 seasons

Staff changes	Frequency	Percentage
No	80	41.24
Yes	114	58.76
Total	194	100.00

Table 10.18 Type of training calf rearing staff had received

Training	Frequency	Percentage
None – farming background	87	44.85
None – on the job training	22	11.34
Workshops, local vet courses	60	30.93
Primary Ag ITO, Ag diploma/ degree, vet/vet nurse	25	12.89
Total	194	100.00

Table 10.19 Whether the farm had experienced any staff issues in past 7 days that had affected the calving routine

Staff issues	Frequency	Percentage
No	187	96.39
Yes	7	3.61
Total	194	100.00

Table 10.20 Whether pregnant heifers were vaccinated for rotavirus/coronavirus pre-calving

Vaccination	Frequency	Percentage
No	135	69.59
Yes	59	30.41
Total	194	100.00

Table 10.21 Location of calving's in the previous 7 days

Location	Frequency	Percentage
Outside-rotational paddock	76	39.18
Outside-specific paddock	109	56.19
Calving pad or indoors	9	4.64
Total	194	100.00

Table 10.22 Whether calves were weighed prior to being sent for processing

Weighed	Frequency	Percentage
No	189	97.42
Yes	5	2.58
Total	194	100.00

Table 10.23 Whether dams experiencing difficult birth were left outside or brought indoors

Location	Frequency	Percentage
Outside	20	10.31
Inside	174	89.69
Total	194	100.00

Table 10.24 How long after birth the calf was separated from dam

Calf separation	Frequency	Percentage
<12 hours	37	19.07
<24 hours	149	76.80
>24 hours	8	4.12
Total	194	100.00

Table 10.25 How many times per day calves were collected from the calving area (where a range was given, the highest value was used)

Minimum	25th percentile	Median	75th percentile	Maximum
1	1	1	2	4

Table 10.26 Method used to transport of calves to calf rearing facility (no information on distance)

Method	Frequency	Percentage
Calf trailer	191	98.45
Walk	2	1.03
Both	1	0.52
Total	194	100.00

Table 10.27 Predominant weather in the previous 7 days

Predominant weather	Frequency	Percentage
Dry	137	70.62
Rain	57	29.38
Total	194	100.00

Table 10.28 Whether any treatment was applied to calf navels

Navel treatment	Frequency	Percentage
No	28	14.43
Yes	166	85.57
Total	194	100.00

Table 10.29 How long after birth navel treatment was applied (hours)

Application time	Frequency	Percentage
≤ 24	169	87.11
> 24	5	2.58
not applicable	20	10.31
Total	194	100.00

Table 10.30 Whether colostrum was pooled on the farm

Pooled	Frequency	Percentage
No	0	0.0
Yes	194	100.00
Total	194	100.00

Table 10.31 Type of first colostrum provided in last 7 days

Colostrum type	Frequency	Percentage
Mixed	22	11.34
True	172	88.66
Total	194	100.00

Table 10.32 Volume of first colostrum feed given

Colostrum volume	Frequency	Percentage
≤ 2 litres	101	52.06
> 2 litres/to fill*	87	44.85
unknown	6	3.09
Total	194	100.00

*to fill=volume not restricted, calves allowed to feed until satiated

Table 10.33 Temperature of first colostrum

Colostrum temperature	Frequency	Percentage
Cold	16	8.25
Warm	178	91.75
Total	194	100.00

Table 10.34 Method of feeding first colostrum in last 7 days

Feeding method	Frequency	Percentage
Dam	5	2.58
Teat bottle	49	25.26
Teat feeder	101	52.06
Tube	39	20.10
Total	194	100.00

Table 10.35 Whether an oesophageal feeder was used if insufficient colostrum is drunk in the first 24 hrs

Oesophageal feeder	Frequency	Percentage
No	28	14.43
Yes	166	85.57
Total	194	100.00

Table 10.36 Whether colostrum quality was measured in the last 7 days

Quality assessed	Frequency	Percentage
No	181	93.30
Yes	13	6.70
Total	194	100.00

Table 10.37 Whether the colostrum feeding procedure differs between bobby and replacement calves

Different feeding procedure	Frequency	Percentage
No	176	90.72
Yes	18	9.28
Total	194	100.00

Table 10.38 Whether the feeding programme differs between bobby and replacement calves

Different feeding programme	Frequency	Percentage
No	148	76.29
Yes	46	23.71
Total	194	100.00

Table 10.39 Type of milk fed to calves (frequency (%) of farms)

	Replacements	Bobbies
Colostrum	14 (7.2)	11 (5.7)
Transition	153 (78.9)	161 (83.0)
Colostrum & transition	26 (13.4)	22 (11.3)
Fermented	1 (0.5)	0 (0)
Total	194 (100)	194 (100)

Table 10.40 Volume of milk fed to calves (frequency (%) of farms)

Milk volume	Replacements	Bobbies
≤2 litres	84 (43.3)	79 (40.7)
2–4 litres	70 (36.1)	74 (38.2)
>4 litres/ad lib	40 (20.6)	39 (20.1)
unknown	0 (0)	2 (1.0)
Total	194 (100)	194 (100)

Table 10.41 Number of feeds per day given to calves (frequency (%) of farms)

Feeds per day	Replacements	Bobbies
1	37 (19.1)	45 (23.2)
2	151 (77.8)	145 (74.7)
>2/ad lib	6 (3.1)	3 (1.6)
unknown	0 (0)	1 (0.5)
Total	194 (100)	194 (100)

Table 10.42 Type of feeding system used for calves (frequency (%) of farms)

Feeding system	Replacements	Bobbies
Automatic feeder	2 (1.0)	0 (0)
Cafeteria	7 (3.6)	6 (3.1)
Dam	0 (0)	1 (0.5)
Multi-teat feeder	185 (95.4)	187 (96.4)
Total	194 (100)	194 (100)

Table 10.43 Temperature of milk fed to calves (frequency (%) of farms)

Milk temperature	Replacements	Bobbies
Cold	51 (26.3)	47 (24.2)
Warm	121 (62.4)	126 (65.0)
Both	22 (11.3)	21 (10.8)

Table 10.44 Whether the milk temperature is checked

Temperature checked	Frequency (%) of farms
Yes	7 (3.6)
No	187 (96.4)
Total	194 (100)

Table 10.45 Type of calf housing (frequency (%) of farms)

Housing type	Replacements	Bobbies
Group	194 (100)	194 (100)
Individual	0 (0)	0 (0)
Total	194 (100)	194 (100)

Table 10.46 Location of calf housing (frequency (%) of farms)

Housing location	Replacements	Bobbies
Indoor	194 (100)	194 (100)
Outdoor	0 (0)	0 (0)
Total	194 (100)	194 (100)

Table 10.47 Whether calf pens had solid walls or bars (frequency (%) of farms)

Wall type	Replacements	Bobbies
Bars	174 (89.7)	173 (89.2)
Solid	17 (8.8)	19 (9.8)
Both	3 (1.5)	2 (1.0)
Total	194 (100)	194 (100)

Table 10.48 Space allowance per calf (m^2)

Space allowance	Replacements	Bobbies
Minimum	0.6	0.4
25th percentile	1.34	1.2
Median	1.75	1.6
75th percentile	2.46	2.03
Maximum	8.3	12.6

Table 10.49 Age at which calves entered the housing unit (days)

Age	Replacements	Bobbies
Minimum	1	1
25th percentile	1	1
Median	1	1
75th percentile	1	1
Maximum	2	2

Table 10.50 Number of days calves spent in the housing unit (where a range was provided, the maximum value was used)

Days	Replacements	Bobbies
Minimum	2	4
25th percentile	10	5
Median	15.5	6
75th percentile	24.5	7
Maximum	70	14

Table 10.51 Type of bedding provided in calf housing (frequency (%) of farms)

Bedding	Replacements	Bobbies
River stones	7 (3.6)	6 (3.1)
Straw	11 (5.7)	17 (8.8)
Wood substrate (chips, shavings, sawdust)	172 (88.7)	164 (84.5)
Wooden slats	4 (2.0)	7 (3.6)
Total	194 (100)	194

Table 10.52 How often the bedding was changed in calf units (frequency (%) of farms)

Bedding changed	Replacements	Bobbies
Weekly	2 (1.0)	2 (1.0)
Monthly	6 (3.1)	7 (3.6)
Once or twice per season	166 (85.6)	167 (86.1)
Every second year	16 (8.2)	13 (6.7)
Never (slatted floors)	4 (2.1)	5 (2.6)
Total	194 (100)	194 (100)

Table 10.53 How often bedding was added to calf pens (frequency (%) of farms)

Bedding added	Replacements	Bobbies
Weekly	26 (13.4)	30 (15.5)
Fortnightly	7 (3.6)	8 (4.1)
Monthly	15 (7.7)	16 (8.2)
Once or twice per season	57 (29.4)	52 (26.8)
Never	89 (45.9)	88 (45.4)
Total	194 (100)	194 (100)

Table 10.54 Whether bedding was changed between groups of calves (frequency (%) of farms)

Bedding changed	Replacements	Bobbies
Yes	6 (3.1)	3 (1.6)
No	188 (96.9)	191 (98.4)
Total	194 (100)	194 (100)

Table 10.55 How often calf housing was cleaned/disinfected (frequency (%) of farms)

Housing disinfected	Replacements	Bobbies
Daily	6 (3.1)	11 (5.7)
Weekly	104 (53.6)	104 (53.6)
Fortnightly or less	43 (22.2)	37 (19.1)
Never	41 (21.1)	42 (21.6)
Total	194 (100)	194 (100)

Table 10.56 Whether air flow was checked in calf housing unit (frequency (%) of farms)

Air flow checked	Replacements	Bobbies
Yes	0 (0)	0 (0)
No	194 (100)	194 (100)
Total	194 (100)	194 (100)

Table 10.57 Age at which bobby calves were separated from replacements in last 7 days

Age	Frequency	Percentage
Birth	119	61.34
1–3 days of age	44	22.68
>3 days of age	31	15.98
Total	194	100.00

Table 10.58 Whether the farmer was advised of the collection time for bobby calves on the day prior to collection

Farmer advised	Frequency	Percentage
N/A (own transport)	2	1.03
No	167	86.08
Yes	25	12.89
Total	194	100.00

Table 10.59 Location of bobby calves at the time of collection in last 7 days

Location	Frequency	Percentage
Rearing pen/shed	98	50.52
Elevated pen/hutch	79	40.72
Ground level pen/hutch	11	5.67
Trailer	6	3.09
Total	194	100.00

Table 10.60 Method of loading calves onto transport

Method	Frequency	Percentage
Manual lift	102	52.58
Walk on	92	47.42
Total	194	100.00

Table 10.61 Whether farm staff were present at the time of collection of bobby calves

Staff present	Frequency	Percentage
No	97	50.00
Yes	97	50.00
Total	194	100.00

Table 10.62 Number of weeks from first calving on farm to collection of case/control calf (proxy for time in season)

Minimum	25th percentile	Median	75th percentile	Maximum
0.1	3.0	6.1	10.1	18

Table 10.63 Duration of travel from farm to processing plant (hours)

n	Mean	Standard deviation
194	3.53	2.24

Appendix 11: Processing plant descriptive statistics

Table 11.1 Type of premises

Premises	Frequency	Percentage
Export	29	90.6
Pet food	3	9.4
Total	32	100.0

Table 11.2 Slaughter schedule

Schedule	Frequency	Percentage
Same	17	53.1
Next	12	37.5
Same/Next[1]	3	9.4
Total	32	100.0

[1] Plants that had a same day schedule at the start of season but switched to next day later in the season

Table 11.3 Number of days out of the past 7 that bobby calves were processed

Minimum	25th percentile	Median	75th percentile	Maximum
1	3	5	6	7

Table 11.4 Whether CCTV was operating in last 7 days

CCTV operating	Frequency	Percentage
No	4	12.5
Yes	28	87.5
Total	32	100.0

Table 11.5 Number of trucks that could be offloaded simultaneously

Minimum	25th percentile	Median	75th percentile	Maximum
1	1	2	2	7

Table 11.6 Whether the offloading ramp is automated

Ramp automated	Frequency	Percentage
No	9	28.1
Yes	23	71.9
Total	32	100.0

Table 11.7 Angle the offloading ramp is set at

Ramp angle	Frequency	Percentage
0 (flat)	1	3.1
≤12 degrees	19	59.4
>12 degrees	5	15.6
unsure/not reported	7	21.9
Total	32	100.0

Table 11.8 Whether the truck/trailer is inspected on arrival at the plant

Truck inspection	Frequency	Percentage
No	2	8.1
Yes	29	91.9
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.9 Number of staff employed to offload trucks in last 7 days

n	Mean	Standard deviation
32	3.8	1.9

Table 11.10 Percentage of offloading staff that were permanent employees

n	Mean	Standard deviation
32	57.0	44.6

Table 11.11 Training received by staff offloading calves

Training	Frequency	Percentage
In-house induction/training programme	16	51.6
On the job training	2	6.5
In-house plus external unit standards (NZQA/AsureQuality)	13	41.9
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.12 Whether truck drivers assist with offloading calves

Drivers unload	Frequency	Percentage
No	0	0.0
Yes	31	100.0
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.13 Who assesses calf condition on arrival at plant. MPI=Ministry for Primary Industries, AWO=animal welfare officer

Calf assessment	Frequency	Percentage
AsureQuality staff	1	3.2
MPI vet and/or AWO	2	6.5
Yard operator or supervisor	16	51.6
Yard operator/supervisor and MPI vet/AWO	12	38.7
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.14 Points at which calf condition is assessed after arrival

Assessment point	Frequency	Percentage
Unloading	15	48.4
Unloading and penning	9	29.0
Unloading and ante mortem	3	9.7
Unloading, penning and ante mortem	4	12.9
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.15 Whether the percentage of wet/scouring calves is recorded for each consignment

Records taken	Frequency	Percentage
No	25	78.1
Yes	7	21.9
Total	32	100.0

Table 11.16 What was done with calves that were unable to walk off the transport (in the last 7 days)

Calf treatment	Frequency	Percentage
Condemned on arrival or priority killed	19	67.9
Put in nursery/side pen for further assessment/feeding	9	32.1
Total*	28	100.0

*4 plants excluded as N/A or no calves unable to walk off in previous 7 days

Table 11.17 Whether nursery pens were used in last 7 days

Nursery pens	Frequency	Percentage
No or N/A	25	78.1
Yes	7	21.9
Total	32	100.00

Table 11.18 SOPs for caring for calves in the nursery pen (where present)

Nursery SOP	Frequency	Percentage
Fed	1	14.3
Checked regularly, fed if required	1	14.3
Priority killed	1	14.3
Assessed, condemned if required	3	42.8
None	1	14.3
Total	7	100.0

Table 11.19 Type of flooring in nursery pen

Nursery flooring	Frequency	Percentage
Mesh or grating	4	57.1
Rubber mat	1	14.3
Sawdust	1	14.3
Not recorded	1	14.3
Total	7	100.0

Table 11.20 Who decides if a calf should be condemned on arrival. MPI=Ministry for Primary Industries, AWO=animal welfare officer

COA assessment	Frequency	Percentage
AQ staff / MPI vet / AWO	7	22.6
Yard operator or supervisor	8	25.8
Yard op/sup and MPI vet	16	51.6
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.21 How long after unloading decision was made to euthanase calves that were condemned on arrival (COA)

COA timing	Frequency	Percentage
<0.5 hour	16	53.3
<1 hour	6	20.0
<2 hours	6	20.0
<3 hours	2	6.7
Total*	30	100.00

*1 N/A, 1 not reported

Table 11.22 Person responsible for euthanasing COA calves in last 7 days. MPI=Ministry for Primary Industries, AWO=animal welfare officer

COA	Frequency	Percentage
Yard operator or supervisor	19	59.4
Yard op/sup and MPI vet/AWO	2	6.2
Staff trained in humane slaughter	6	18.8
AWO / AsureQuality staff	2	6.2
Not applicable/not reported	3	9.4
Total	32	100.0

Table 11.23 Method used to euthanase COA calves

Method	Frequency	Percentage
Captive bolt + stick	29	93.5
Shotgun	1	3.25
Not reported	1	3.25
Total	31	100.0

Table 11.24 Number of staff involved in penning calves in the last 7 days

n	Median	Min	Max	Q1	Q3
31	3	1	7	2	4

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.25 Method used to move calves from offloading to pens

Method	Frequency	Percentage
Both	5	16.1
Flappers	7	22.6
Rattles	19	61.3
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.26 Training received by staff involved in penning calves. NZQA=New Zealand Qualifications Authority

Training	Frequency	Percentage
In-house induction/training programme	16	51.6
On the job training	2	6.5
In-house plus external unit standards (NZQA/AsureQuality)	13	41.9
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.27 Whether feed was provided in lairage pens in the last 7 days (volume, number feeds, type feed, temp, method)

Feed provided	Frequency	Percentage
No	27	87.1
Yes	4	12.9
Total	31	100.0

NB: Only 1 plant reported routinely providing feed in lairage; a further 5 plants reported feeding only when time off feed regulations require

Table 11.28 The type of flooring in lairage pens

Lairage flooring	Frequency	Percentage
Grating	17	53.1
Mesh	11	34.4
Grating and mesh	1	3.1
Concrete +/- rubber*	3	9.4
Total	32	100.00

*Concrete flooring was used by pet food plants only

Table 11.29 Minimum space allowance per calf in lairage (m^2) in past 7 days

Minimum	25th percentile	Median	75th percentile	Maximum
0.2	0.3	0.35	0.4	0.9

Table 11.30 Maximum length of time (hours) calves were held in lairage before processing in the last 7 days (range)

Minimum	25th percentile	Median	75th percentile	Maximum
0.9	3.2	5.0	10.0	23.0

Table 11.31 Who decided if the calf should be condemned in the yard in last 7 days. MPI=Ministry for Primary Industries, AWO=animal welfare officer

CIY assessment	Frequency	Percentage
AQ staff / MPI vet / AWO	7	22.6
Yard operator or supervisor	8	25.8
Yard op/sup and MPI vet	16	51.6
Total*	31	100.0

*1 pet food plant excluded; calves killed in the truck on arrival

Table 11.32 Person responsible for euthanasing calves condemned in yard in last 7 days. MPI=Ministry for Primary Industries, AWO=animal welfare officer

COA	Frequency	Percentage
Yard operator or supervisor	22	71.0
Yard op/sup and MPI vet/AWO	3	9.7
Staff trained in humane slaughter	5	16.1
AWO	1	3.2
Total	31	100.0

Table 11.33 Method used to euthanase condemned in yard calves in last 7 days

Method	Frequency	Percentage
Captive bolt + stick	20	96.7
Shotgun	1	3.3
Total	31	100.0

Table 11.34 Number of staff trained in humane slaughter of calves

n	Mean	Standard deviation
30	6.0	3.37

Table 11.35 Method used to move calves to slaughter holding pens

Method	Frequency	Percentage
Rattles	19	61.3
Flappers	5	16.1
Rattles and flappers	5	16.1
Ushering	2	6.5
Total	31	100.0

Table 11.36 Chain speed used in past 7 days

n	Mean	Standard deviation
30*	4.6	1.38

*Two pet food plants operated manual chains

Table 11.37 Training received by staff processing calves

Training type	Frequency	Percentage of plants
Health and safety	20	62.5
Compliance	3	9.4
Food hygiene	15	46.9
Humane slaughter	7	21.9
Animal welfare	7	21.9
Stunning	1	3.1
Job/task specific training	7	21.9
External standards	4	12.5

NB: Individual plants reported multiple training types, percentage refers to proportion of plants that used the specified training type

Table 11.38 Predominant weather in past 7 days

Weather	Frequency	Percentage
Dry	26	81.3
Wet	6	18.7
Total	32	100.0

Table 11.39 Whether there were any significant management changes with regard to processing bobby calves between the 2015 and 2016 spring calving seasons

Management changes	Frequency	Percentage
No	5	15.6
Yes	27	84.4
Total	32	100.0

Table 11.40 Number of calves received in the last 7 days (throughput)

Minimum	25th percentile	Median	75th percentile	Maximum
799	1541	2730	11379	17500

*includes export plants only

Table 11.41 Percentage of calves received in past 7 days that died or were condemned (DOA/COA/DIY/CIY)

Minimum	25th percentile	Median	75th percentile	Maximum
0	0.03	0.095	0.215	0.71

*includes export plants only

Appendix 12: Variables included in case control univariate analyses

Independent variables extracted from the farm, transporter and processing plant questionnaires that were submitted to univariate analysis to explore their effects on the likelihood of calf mortality (i.e. being a case) are described below. Variables marked with an asterisk (P<0.20) were subsequently included in the multivariate analysis.

Farm:

Variable	Definition
Farm type	Dairy or mixed livestock farm
Farm location	North or South Island
Enterprise type	Conventional or organic
Operating structure	Contract milker, equity partnership, manager, owner, share milker
Predominant breed	Friesian/ Friesian cross, Jersey/ Jersey cross, other
Calving pattern*	Spring, split; based on when majority of herd (>80%) calved
Herd size	Number of milking cows on farm
Annual replacement rate	% of herd replaced each year
Labour	Number of staff involved in day-to-day care of calves
Bobby calf rearer	Presence of dedicated bobby calf rearer
Gender of bobby calf rearer	Male or female
Calf rearer farming experience	Number of years primary calf rearer spent in livestock farming
Calf rearer bobby calf experience	Number of years primary calf rearer spent rearing bobby calves
Calf rearer status	Family member full time, family member part time, paid employee full time, paid employee part time
Time spent calf rearing	Number of hours per day spent on calf rearing
Management changes	Yes/no; There have been management changes on farm since last calving season
Training	Formal training in calf rearing: none, farming background; none, on the job training; workshops/short courses; Ag ITO or university degree
Staff issues*	Any changes to the daily routine in the week of calf selection that might have affected the calves
Vaccination	Yes/no; Vaccination status of pregnant cows/heifers prior to calving
Calf sex	Male or female
Calving management	Location of calving: Outside in rotational paddock; outside in specific calving paddock; specific calving pad
Location for difficult calvings	Outside or inside

Variable	Definition
Separation from dam	Time between calving and separation from dam (hours); Less than 12, less than 24, more than 24
Number of calf collections per day	Number of times per day calves collected from calving paddock
Transport to calf shed	Features of transport from calving area to calf shed; Calf trailer mesh floor, calf trailer solid floor, calf trailer floor covering, walked
Navel treatment	Yes/no; bobby calf navel treated
Type of first colostrum feed*	Type of first colostrum feed; true colostrum, mixed colostrum
Volume of first colostrum	Volume of first colostrum feed (L)
Method of first colostrum	Method used to feed first colostrum; Dam, teat feeder, tube, teat bottle
Temperature of first colostrum	Cold or warm
Measurement of first colostrum quality*	Yes/no; quality of first colostrum fed measured using colostrometer, RID assay or refractometer
Different colostrum feeding programmes	Yes/no; different colostrum feeding programme used for replacement heifers and bobby calves
Different milk feeding programmes	Yes/no; different milk feeding programme used for replacement heifers and bobby calves
Number of feeds per day	Number of times bobby calves fed per day
Volume of milk fed per day	Total volume of milk fed to bobby calves per day
Temperature of milk fed	Cold, warm, both
Access to water	Yes/no; Bobby calves had access to water on farm
Type of housing	Type of housing for bobby calves; solid walls, open walls, both
Housing group size	Size of groups of bobby calves housed together
Stocking density	Stocking density for bobby calves during housing on farm
Days in housing*	Number of days spent in the housing unit
Calf house bedding	Type of bedding used in bobby calf housing; river stones, sawdust, straw, woodchip, wood shavings, wooden slats
Frequency of bedding change	How often bobby calf housing bedding changed; never, end of season, once/season, twice/season, more than twice/season, monthly, fortnightly, weekly
Frequency of adding bedding	How often bedding added to calf housing during season; never, once/season, twice/season, more than twice/season, monthly, fortnightly, weekly
Frequency of disinfection of bobby calf housing	How often disinfectant was sprayed onto bedding in bobby calf housing during season; never, once/season, more than twice/season, fortnightly, weekly, daily
Day of separation*	Age at which bobby calves were separated from replacement heifers; < 1 day old, 1-3 days old, ≥ 4 days old
Calf weighing	Yes/no; Bobby calves were weighed on farm prior to transport
Predominant weather*	Predominant weather conditions on farm over last seven days from date of calf selection; dry, rain

Transport:

Variable	Definition
Location at collection*[a]	Location of bobby calves for collection from the farm; rearing pen or collection pen in same rearing shed, elevated pen or hutch, ground level pen or hutch near calf shed or trailer
Loading method*[a]	Method of loading bobby calves onto transport truck; manual lift, walk onto truck
Staff member present[a]	Yes/no; staff member present at time of calf collection
Time in farm's season*[a]	Number of weeks between first calving on the farm and collection of the selected calf
Travel time*[b]	Total number of hours travelled by selected calf from farm to processing plant

[a] information obtained from farm survey
[b] information obtained from processing plant docket for calves where no transporter information was available

Processing plant:

Variable	Definition
Slaughter schedule*	Whether the selected calf was slaughtered at premises operating a same day or next day slaughter schedule
Ramp automated	Whether the unloading ramp is automated
Ramp angle	Angle the ramp is set at
Truck inspection	Whether the truck/trailer is inspected on arrival
Who assesses calves on arrival	Who is responsible for assessing calf condition on arrival
When calf condition is assessed	At what point during processing calf assessment is done
Type of flooring in lairage	Type of flooring in bobby calf lairage
Staff trained in humane slaughter	Number of staff trained in humane slaughter of bobby calves
Management change 2015/2016	Whether there have been any significant changes to the processing of bobby calves between 2015 and 2016 seasons
Time in plant's season*	Number of weeks between plant's first bobby calf processing event of the season and arrival of the selected calf

Appendix 13 – Verbatim post mortem findings and diagnoses for case calves

Table 13.1 Post mortem findings in 22 of 38 calves for which an explicit diagnosis was recorded, including one for which the diagnosis was No Significant Findings. Diagnoses are listed in alphabetical order

Diagnosis
Abomasal ulceration
Autolysis (NSF)
Blind in both eyes (congenital cataract)
Suffocation
Emaciated
Enteritis
Left lung congested with blood, bruising to abomasum and limbs
Metabolic pathology
Minimal renal fat otherwise condition acceptable
Peritonitis
Peritonitis and associated septicaemia
Pneumonia
Inflammation related to umbilical/urachus
Septicaemia
Severe chronic peritonitis
Simple fracture to right tibia
Small intestinal enteritis, scours, dehydration
Strangulated umbilical hernia
Sub-acute bruising to right hind leg, no significant pathology in leg
Ulcers noted in abomasum, no other indication of cause of death
Watery diarrhoea, intestinal inflammation, haemorrhage in pelvic cavity, septic arthritis
No significant findings

Appendix 14: Results of case/control study univariate analyses

Table 14.1 Results of univariate logistic regression analysis of all explanatory variables for calf mortality using all cases (n=38) and controls (n=156)

Variable	Case calves (n = 38)	Control calves (n = 156)	P-value
Sex of calf %			0.696
Male	66	72	
Female	34	28	
Farm location %			**0.047**
North Island	71	53	
South Island	29	47	
Farm type %			1
Dairy	92	90	
Mixed	8	10	
Operating structure %			1
Owner/operator	61	60	
Share milker	21	21	
Contract milker/manager	18	19	
Calving pattern %			**0.082**
Spring	84	94	
Split	16	6	
Breed of calf %			0.231
Friesian/Friesian cross	68	51	
Jersey/Jersey cross	11	12	
Kiwi cross	18	33	
Other	3	4	
Herd size median (range)	615 (215–1700)	665 (120–2500)	0.513
Number of replacements median (range)	150 (45–500)	150 (0–750)	0.711
Annual replacement rate % median (range)	24 (17–46)	23 (0–39)	0.274
Number of staff caring for calves median (range)	1.5 (1–6)	2.0 ()1–6	0.247
Dedicated bobby calf rearer %			0.749
Yes	11	8	
No	89	92	
Calf rearer farming experience median (range)	16 (2–50)	20 (1–50)	0.750
Calf rearer bobby calf experience median (range)	10.5 (1–30)	10 (1–50)	0.535

Variable	Case calves (n = 38)	Control calves (n = 156)	P-value
Calf rearer status %			0.683
Family full time	39	46	
Family part time	16	10	
Paid full time	34	30	
Paid part time	11	14	
Time spent calf rearing calves %			0.446
≤ 3 hours	40	29	
3.6–6 hours	34	31	
>6 hours	26	30	
Management changes since last season %			0.625
Yes	55	60	
No	45	40	
Training %			0.379
None, farming background	18	30	
On the job training	50	40	
Workshops, short local vet course	16	11	
Primary Ag ITO, Diploma or Degree Ag Science/Vet/Vet nurse	16	19	
Staff issues in past 7 days %			**0.137**
Yes	8	3	
No	92	97	
Vaccination of pregnant heifers %			0.315
Yes	24	32	
No	76	68	
Calving location %			0.572
Outside rotational paddock	34	40	
Outside specific paddock	63	55	
Calving pad or indoors	3	5	
Whether calves are weighed %			0.585
Yes	0	3	
No	100	97	
Location for difficult birth %			0.375
Outside	5	12	
Inside	95	88	
Separation from dam %			0.561
<12 hours	13	21	
≤24 hours	82	76	
>24 hours	5	3	

Variable	Case calves (n = 38)	Control calves (n = 156)	P-value
Calf collections per day median (range)	1.0 (1–3)	1.0 (1–4)	0.383
Transport to calf shed %			0.690
Walk	0	2	
Trailer	100	98	
Predominant weather past 7 days %			**0.128**
Dry	61	73	
Wet	39	27	
Navel treatment %			0.803
Yes	87	85	
No	13	15	
Timing of navel treatment %			0.504
≤24 hours	84	88	
>24 hours	5	2	
None	11	10	
Whether colostrum is pooled %			1
Yes	100	100	
No	0	0	
Type of first colostrum %			**0.152**
True	82	90	
Mixed	18	10	
Volume of first colostrum %			0.317
≤2 litres	47	55	
>2 litres/ad lib	53	45	
Temperature of first colostrum %			0.523
Cold	11	8	
Warm	89	92	
Method of first colostrum %			0.405
Dam	0	3	
Teat bottle	29	24	
Teat feeder	58	51	
Tube	13	22	
Measurement of colostrum quality %			**0.076**
Yes	0	8	
No	100	92	
Use of oesophageal feeder %			0.791
Yes	84	86	
No	16	14	

Variable	Case calves (n = 38)	Control calves (n = 156)	P-value
Different colostrum feeding programme %			0.534
Yes	5	10	
No	9590		
Different milk feeding programme %			0.997
Yes	24	24	
No	76	76	
Type of milk fed %			0.922
Colostrum	5	6	
Transition	82	83	
Both	13	11	
Volume of milk per day %			0.767
≤2 litres	42	38	
2–4 litres	42	41	
>4 litres/ad lib/to fill	16	21	
Number of milk feeds per day %			0.758
1	26	23	
2	74	75	
>2/ad lib	0	2	
Type of feeding system %			0.869
Dam	0	1	
Cafeteria	3	3	
Multi-teat	97	96	
Temperature of milk fed %			0.793
Cold	26	24	
Warm	60	66	
Both	14	10	
Milk temperature checked %			1
Yes	3	4	
No	97	96	
Housing walls %			0.702
Bars	92	88	
Solid	8	10	
Both	0	2	
Space allowance median (range)	1.59 (0.72–5.33)	1.58 (0.40–12.6)	0.437
Age entering housing unit %			0.354
≤1 day old	97	99	
>1 day old	3	1	

Variable	Case calves (n = 38)	Control calves (n = 156)	P-value
Days spent in housing unit median (range)	6.5 (4–11)	6.0 (4–14)	**0.129**
Type of bedding %			0.432
Wood chips/shavings/sawdust	82	84	
Straw	5	10	
River stones	5	3	
Wooden slats	8	3	
Frequency of bedding change %			0.438
Weekly	0	1	
Monthly	0	4	
1–2 per season	94	84	
Every second year	3	8	
Never	3	3	
Frequency of bedding added %			0.714
Weekly	13	16	
Fortnightly	3	4	
Monthly	5	9	
1–2 per season	24	28	
Never	55	43	
Bedding changed between groups %			0.482
Yes	3	1	
No	97	99	
Frequency of housing disinfection %			0.754
Daily	16	23	
Weekly	5	6	
Fortnightly or less	61	52	
Never	18	19	
Day of separation %			**0.015**
Birth	53	63	
1–3 days	39	19	
>3 days	8	18	
Location at collection %			**0.012**
Rearing pen	61	48	
Elevated hutch	21	46	
Ground level pen	10	4	
Trailer	8	2	
Loading method %			**0.029**
Manual lift	68	49	
Walk on	32	51	

Variable	**Case calves (n = 38)**	**Control calves (n = 156)**	**P-value**
Staff member present at collection %			0.278
Yes	58	48	
No	42	52	
Weeks in farm’s season median (range)	9.15 (2.0–13.3)	5.2 (0.1–18.0)	**<0.001**
Travel duration (minutes) median (range)	337.5 (45–600)	165 (5–600)	**<0.001**
Slaughter schedule %			**<0.001**
Same day	26	63	
Next day	74	37	
Ramp automated %			1
Yes	89	87	
No	11	13	
Ramp angle %			1
≤12 degrees	88	88	
>12 degrees	12	12	
Truck inspection %			**0.076**
Yes	100	91	
No	0	9	
Who assesses calves on arrival %			**0.024**
AQ staff	3	12	
MPI vet/AWO	0	3	
Yard operator/supervisor	74	47	
Yard op/sup + MPI vet/AWO	23	38	
When calf condition is assessed %			**0.078**
Unloading	63	62	
Unloading + penning	29	24	
Unloading + ante mortem	8	3	
Unloading + penning + ante mortem	0	11	
Number of staff trained in humane slaughter median (range)	5 (3–19)	5 (2–19)	0.778
Management change from 2015–2016 %			0.690
Yes	95	96	
No	5	4	
Weeks in plant’s season median (range)	10.9 (3.7–20)	5.7 (0–20)	**<0.001**

AQ= AsureQuality; MPI= Ministry for Primary Industries; AWO= animal welfare officer

Table 14.2 Results of univariate logistic regression analysis of all explanatory variables for calf mortality using all controls (n=156) and cases that died or were condemned in the yard (DIY/CIY; n=18)

Variable	**Case calves (n = 18)**	**Control calves (n = 156)**	**P-value**
Sex of calf %			0.687
Male	71	68	
Female	29	32	
Farm location %			0.277
North Island	67	53	
South Island	33	47	
Farm type %			0.525
Dairy	94	90	
Mixed	6	10	
Operating structure %			0.812
Owner/operator	56	60	
Share milker	28	21	
Contract milker/manager	16	19	
Calving pattern %			**0.032**
Spring	78	94	
Split	22	6	
Breed of calf %			**0.133**
Friesian/Friesian cross	78	51	
Jersey/Jersey cross	11	12	
Kiwi cross	11	33	
Other	0	4	
Herd size median (range)	645 (215–1700)	665 (120–2500)	0.849
Number of replacements median (range)	160 (45–500)	150 ()0–750	0.901
Annual replacement rate % median (range)	24 (17–36)	23 (0–39)	0.347
Number of staff caring for calves median (range)	1.25 (1–4)	2.0 (1–6)	**0.160**
Dedicated bobby calf rearer %			0.219
Yes	17	8	
No	83	92	
Calf rearer years farming median (range)	18.5 (5–30)	20 (1–50)	0.799
Calf rearer years bobby calf rear median (range)	13.0 (2–30)	10 (1–50)	0.709
Calf rearer status %			0.870
Family full time	44	46	
Family part time	17	10	
Paid full time	28	30	
Paid part time	11	14	

Variable	**Case calves (n = 18)**	**Control calves (n = 156)**	**P-value**
Time spent calf rearing calves %			0.539
≤ 3 hours	39	29	
3–6 hours	28	31	
>6 hours	33	30	
Management changes since last season %			0.433
Yes	50	60	
No	50	40	
Training %			0.614
None, farming background	22	30	
On the job training	50	40	
Workshops, short local vet course	17	11	
Primary Ag ITO, Diploma or Degree Ag Science/Vet/Vet nurse	11	19	
Staff issues in past 7 days %			**0.118**
Yes	11	3	
No	89	97	
Vaccination of pregnant heifers %			0.393
Yes	22	32	
No	78	68	
Calving location %			0.460
Outside rotational paddock	33	40	
Outside specific paddock	67	55	
Calving pad or indoors	0	5	
Calf weighing %			1
Yes	0	3	
No	100	97	
Location for difficult birth %			0.222
Outside	0	12	
Inside	100	88	
Separation from dam %			0.921
<12 hours	22	21	
≤24 hours	72	76	
>24 hours	6	3	
Calf collections per day median (range)	1 (1–3)	1 (1–4)	0.865
Transport to calf shed %			0.839
Walk	0	2	
Trailer	100	98	

Variable	**Case calves (n = 18)**	**Control calves (n = 156)**	**P-value**
Predominant weather past 7 days %			1
Dry	72	73	
Wet	28	27	
Navel treatment %			1
Yes	89	85	
No	11	15	
Timing of navel treatment %			0.524
≤24 hours	88	88	
>24 hours	6	2	
None	6	10	
Type of first colostrum %			0.405
True	83	90	
Mixed	17	10	
Whether colostrum is pooled %			1
Yes	100	100	
No	0	0	
Volume of first colostrum %			**0.186**
≤2 litres	39	55	
>2 litres/ad lib	61	45	
Temperature of first colostrum %			0.642
Cold	11	8	
Warm	89	92	
Method of first colostrum %			0.208
Dam	0	3	
Teat bottle	6	24	
Teat feeder	72	51	
Tube	22	22	
Measurement of colostrum quality %			0.366
Yes	0	8	
No	100	92	
Use of oesophageal feeder %			1
Yes	11	14	
No	89	86	
Different colostrum feeding programme %			1
Yes	6	10	
No	94	90	

Variable	**Case calves (n = 18)**	**Control calves (n = 156)**	**P-value**
Different milk feeding programme %			0.772
Yes	28	24	
No	72	76	
Type of milk fed %			0.999
Colostrum	6	6	
Transition	11	11	
Both	83	83	
Volume of milk per day %			0.463
≤2 litres	33	38	
2–4 litres	44	41	
>4 litres/ad lib/to fill	22	21	
Number of milk feeds per day %			0.521
1	33	23	
2	67	75	
>2/ad lib	0	2	
Type of feeding system %			0.699
Dam	0	1	
Cafeteria	0	3	
Multi-teat	100	94	
Temperature of milk fed %			0.251
Cold	28	24	
Warm	50	66	
Both	22	10	
Milk temperature checked %			1
Yes	0	4	
No	100	96	
Housing walls %			0.314
Bars	100	88	
Solid	0	10	
Both	0	2	
Space allowance median (range)	1.54 (0.73–5.33)	1.58 (0.4–12.6)	0.873
Age entering housing unit %			**0.197**
≤1 day old	94	99	
>1 day old	6	1	
Days spent in housing unit median (range)	6 (4–11)	6 (4–14)	**0.039**

Variable	Case calves (n = 18)	Control calves (n = 156)	P-value
Type of bedding %			0.322
Wood chips/shavings/sawdust	77	84	
Straw	6	10	
River stones	11	3	
Wooden slats	6	3	
Frequency of bedding change %			0.498
Weekly	0	1	
Monthly	0	4	
1–2 per season	100	84	
Every second year	0	8	
Never	0	3	
Frequency of bedding added %			0.815
Weekly	17	16	
Fortnightly	5.5	4	
Monthly	5.5	9	
1–2 per season	17	28	
Never	55	43	
Bedding changed between groups %			1
Yes	0	1	
No	100	99	
Frequency of housing disinfection %			**0.104**
Daily	0	23	
Weekly	11	6	
Fortnightly or less	72	52	
Never	17	19	
Air quality checked			
Yes	0	0	1
No	100	100	
Day of separation %			**0.088**
Birth	56	63	
1–3 days	39	19	
>3 days	5	18	
Location at collection %			**0.014**
Rearing pen	72	48	
Elevated hutch	17	46	
Ground level pen	0	4	
Trailer	11	2	

Variable	Case calves (n = 18)	Control calves (n = 156)	P-value
Loading method %			**0.059**
Manual lift	72	49	
Walk on	28	51	
Staff member present at collection %			**0.135**
Yes	33	52	
No	67	48	
Weeks in farm's season median (range)	8.15 (4.0–13.3)	5.2 (0.1–18.0)	**0.012**
Travel duration (minutes) median (range)	350 (90–570)	165 (5–600)	**<0.001**
Slaughter schedule %			**0.016**
Same day	33	63	
Next day	67	37	
Ramp automated %			0.701
Yes	94	87	
No	6	13	
Ramp angle %			0.829
≤12 degrees	93	88	
>12 degrees	7	12	
Truck inspection %			0.367
Yes	100	91	
No	0	9	
Who assesses calves on arrival %			0.351
AQ staff	0	12	
MPI vet/AWO	0	3	
Yard operator/supervisor	61	47	
Yard op/sup + MPI vet/AWO	39	38	
When calf condition is assessed %			0.431
Unloading	72	62	
Unloading + penning	22	24	
Unloading + ante mortem	6	3	
Unloading + penning + ante mortem	0	11	
Number of staff trained in humane slaughter median (range)	5 (3–19)	5 (2–19)	0.472
Management change from 2015–2016 %			0.433
Yes	50	60	
No	50	40	
Weeks in plant's season median (range)	10.9 (3.7–20.0)	5.7 (0–20.0)	**0.016**

AQ= AsureQuality; MPI= Ministry for Primary Industries; AWO= animal welfare officer

Appendix 15: Summary of articles retrieved in systematic literature review of potential welfare indicators in bobby calves

Table 15.1 Animal- and Resource-based indicators of Nutritional or Hydration status (Domain 1) addressed in articles retrieved during the systematic mapping (n=253)

Welfare Indicator	Number of Studies (%) n=253	Reference
Body Weight	75 (29.7)	Arthington et al., 2003; Bernardini et al., 2015; Blaxter & Wood, 1951; Buckham Sporer et al., 2008; Cafazzo et al., 2012; Constable, et al., 1998; Crookshank et al., 1979; de la Fuente et al., 2010; de Wilt, 1985; Diesch, 2002; Duve et al., 2012; Earley & Murray, 2010; Earley et al., 2012; Ekpe & Christopherson, 2000; Fernandez et al., 1996; Fisher et al., 2014; Fregonesi & Leaver, 2001; Ganheima et al., 2007; Goldhawk, 2014; Gonzalez, et al., 2012a; Gonzalez, et al., 2012b; Gottardo, et al., 2002; Gupta, et al., 2005; Grasso, et al., 1999; Grigor, et al., 2001; Gupta, et al., 2007; Hänninen, et al., 2003; Hänninen, et al., 2005; Ibanez, et al., 2002; Jago, et al., 1999; Jasper, et al., 2008; Kent & Ewbank, 1986; Kertz, et al., 1984; Kirton & Paterson, 1973; Knowles, et al., 1997; Knowles, et al., 1999; Lensink, et al., 2000; Lidfors, 1993; Llonch, et al., 2015; Lürzel, et al,. 2015a; Marques, et al., 2012; Mogensen, et al., 1997; Molony & Kent, 1997; Morisse, et al., 2000; Munksgaard, et al., 1999; Panivivat, et al., 2004; Parker, et al., 2003; Petherick, et al., 2009; Prevedello, et al., 2012; Pritchard, et al., 2008; Rushen & de Passillé, 1995; Schrama, 1992a; Schrama, et al., 1996; Schwartzkopf-Genswein, et al., 2007; Scott & Christopherson, 1993; Smulders, et al., 2006; Stafford, et al., 2001; Stephens & Toner, 1975; Stockman, et al., 2012; Stull & McDonough, 1994; Tapkı, et al., 2006; Todd, 1998; Todd, et al., Veissier., et al, 1989; Veissier, et al., 1998; Veissier, et al., 2001; Webb, et al., 2012; Webster, et al., 2008; Webster, et al., 1978; Wesselink, 1998; White, et al., 2009; Xiccato, et al., 2002
Feeding	27 (10.7)	Ahsan, et al., 2014; Bähler, et al., 2012; Bergman, et al., 2014; Boissy, et al., 2001; Brown-Brandl, et al., 2005; Ekpe & Christopherson, 2000; Fregonesi & Leaver, 2001; Howard, 2004; Kertz, et al., 1984; Kirton & Paterson, 1973; Kooijman, et al., 1991; Krachun, et al., 2010; Margerison, et al., 2003; Molony & Kent, 1997; Morisse, et al., 2000; Olsen, et al., 1980; Parker, et al., 2003; Rushen & de Passillé, 1995; Sandström, 2009; Schrama, 1992a; Schrama, et al., 1993a; Schrama, et al., 1993b; Schrama, et al., 1995; Scott & Christopherson, 1993; Stanković, et al., 2014; Todd, et al., 2000; Veissier, et al., 1989
Body Condition Score	10 (4.0)	Bergman, et al., 2014; Bršċić, et al., 2012; Diesch, 2002; Fregonesi & Leaver, 2001; Huxley, et al., 2004; Llonch, et al., 2015; Petherick, et al., 2009; Pritchard, et al., 2008; Regula, et al., 2004; Takacova, et al., 2012

Welfare Indicator	Number of Studies (%) n=253	Reference
Water supply	9 (3.6)	Ahsan, et al., 2014; Bähler, et al., 2012; Garner, 2005; Howard, 2004; Kertz, et al., 1984; Parker, et al., 2003; Parker, et al., 2004; Sandström, 2009; Schrama, et al., 1993b

Table 15.2 Animal- and Resourced-based indicators of Environment-related welfare-relevant factors (Domain 2) addressed in articles retrieved during the systematic mapping (n=253)

Welfare Indicator	Number of Studies (%) n=253	Reference
Ambient Temperature	39 (15.4)	Ames & Insley, 1975; Averos, et al., 2007; Bernardini, et al.,2015; Brown-Brandl, et al., 2005; Cafazzo, et al., 2012; Diesch, 2002; Earley, et al., 2006; Earley & Murray, 2010; Earley & O'Riordan, 2006; Earley, et al., 2012; Fazio, et al., 2008; Goldhawk, 2014; González, et al., 2012a; González, et al., 2012b; Ibanez, et al., 2002; Jacobson & Cook, 1998; Kent & Ewbank, 1986; Knowles, et al., 1997; Knowles, et al., 1999; Mohr, et al., 2002; Pettiford, et al., 2008; Schrama, 1992a; Schrama, et al., 1993a; Schrama, et al., 1993b; Schrama, et al., 1995; Scott & Christopherson 1993; Stewart, et al., 2010; Stockman, et al., 2011; Stockman, et al., 2013; Stull & McDonough, 1994; Uetake, et al., 2011; Vermorel, 1989; Vermorel, et al., 1983; Webster, et al., 2008; Webster, et al., 1978; Webster, et al., 1985; Weschenfelder, et al., 2012; Wickham, et al., 2015; Zähner, et al., 2004
Space allowance	28 (11.1)	Abdelfattah, et al., 2013; Bähler, et al., 2012; Bergman, et al., 2014; Bokkers & Koene, 2001; Bršćić, et al., 2011; Bršćić, et al., 2012; Cozar, et al 2016; Fisher, et al., 1997; Garner, 2005; Gonzalez, et al., 2012b; Grasso, et al., 1999; Grigor, et al., 2004; Gupta, et al., 2007; Ibanez, et al., 2002; Jensen & Kyhn, 2000; Jensen, 1999; Jensen, et al., 1997; Kent & Ewbank, 1986; Leruste, et al., 2012b; Leruste, et al., 2014; Lidfors, 1993; Mogensen, et al., 1997; Sandström, 2009; Tapkı, et al., 2006; Tarrant, et al., 1988; Todd, 1998; Uetake, et al., 2011; White, et al., 2009
Relative Humidity	22 (8.7)	Averos, et al., 2007; Bernardini, et al.,2015; Brown-Brandl, et al., 2005; Cafazzo, et al., 2012; Earley, et al., 2006; Earley & Murray, 2010; Earley & O'Riordan, 2006; Fazio, et al., 2008; Goldhawk, 2014; Knowles, et al., 1999; Schrama, et al., 1993a; Schrama, et al., 1993b; Stewart, et al., 2010; Stockman, et al., 2011; Stockman, et al., 2013; Stull & McDonough, 1994; Uetake, et al., 2011; Webster, et al., 1985; Webster, et al., 2008; Weschenfelder, et al., 2012; Wickham, et al., 2015; Zähner, et al., 2004
Environmental Conditions	12 (4.7)	Brown-Brandl, et al., 2005; Cafazzo, et al., 2012; Earley, et al., 2006; Earley & Murray, 2010; Earley & O'Riordan, 2006; Earley, et al., 2012; Garner, 2005; Leruste, et al., 2012b; Leruste, et al., 2014; Pettiford, et al., 2008; Regula, et al., 2004; Scott & Christopherson, 1993
Flooring	12 (4.7)	Ahsan, et al., 2014; Bršćić, et al., 2011; Bršćić, et al., 2012; Fisher, et al., 1997; Garner, 2005; Haley, et al., 2001; Hänninen, et al., 2003; Leruste, et al., 2014; Mogensen, et al., 1997; Sandström, 2009; Stockman, et al., 2013; Stull & McDonough, 1994
Bedding	7 (2.8)	Howard, 2004; Kent & Ewbank, 1986; Mogensen, et al., 1997; Panivivat, et al., 2004; Peli, et al., 2016; Regula, et al., 2004; Sandström, 2009
Wind Speed	6 (2.4)	Ames & Insley, 1975; Brown-Brandl, et al., 2005; Schrama, et al., 1993; Webster, et al., 1978; Webster, et al., 1985; Webster, et al., 2008

Welfare Indicator	Number of Studies (%) n=253	Reference
Housing	4 (1.6)	Dalmau, et al., 2009; Peli, et al., 2016; Stanković, et al., 2014; Tarrant, et al., 1988
Light levels	2 (0.8)	Garner, 2005; Stull & McDonough, 1994
Noise	2 (0.8)	Sandström, 2009; Todd, 1998
Noxious Gases	2 (0.8)	Stull & McDonough, 1994; Panivivat, et al., 2004
Windchill	2 (0.8)	Ames & Insley, 1975; Webster, et al., 2008
Cleaning	1 (0.4)	Bokkers & Koene, 2001
Shade	1 (0.4)	Brown-Brandl, et al., 2005
Slipping	1 (0.4)	Ahsan, et al., 2014
Rainfall	1 (0.4)	Webster, et al., 2008
Vibration	1 (0.4)	Van De Water, et al., 2003a

Table 15.3 Animal- and Resource-based indicators of Health/Functional status (Domain 3) addressed in articles retrieved during the systematic mapping (n=253)

Welfare Indicator	Number of Studies (%) n=253	Reference
Blood components	149 (58.9)	Abdelfattah, et al., 2013; Amadori, et al., 1997; Arthington, et al., 2003; Averos, et al., 2007; Barrier, et al., 2013; Becker, et al., 1989; Bernardini, et al., 2015; Blecha, et al., 1984; Bokkers, et al., 2009; Bourguet, et al., 2010; Braun, et al., 1982; Buckham Sporer, 2007; Buckham Sporer, et al., 2008; Cabello & Michel, 1977; Cafazzo, et al., 2012; Candiani, et al., 2008; Cockram, et al., 1999; Cole, et al., 1986; Constable, et al., 1998; Cooper, et al., 1995; Cozar, et al., 2016; Crookshank, et al., 1979; Cucuzza, et al., 2014; De la Fuente, et al., 2010; de Wilt, 1985; Diesch, 2002; Diesch, et al., 2004; Earley, et al., 2006; Earley & Murray, 2010; Earley & O'Riordan, 2006; Earley, et al., 2012; Ekpe & Christopherson, 2000; Fazio, et al., 2008; Fell & Shutt, 1986; Fisher, et al., 2014; Fisher, et al., 1997; Fröhli & Blum, 1988; Gånheim, et al., 2007; Garner, 2005; Giannetto, et al., 2011; Goldhawk, 2014; Grasso, et al., 1999; Gottardo, et al., 2002; Grigor, et al., 2001; Grigor, et al., 2004; Groutides & Michell, 1990; Gupta, et al., 2007; Gupta, et al., 2005; Hänninen, et al., 2005; Hemsworth, et al., 2011; Hudson, et al., 1976; Ibáñez, et al., 2002; Ishiwata & Kariya, 2010; Jacob, et al., 2001; Jarvis, et al., 1996; Johnston & Buckland, 1976; Jongman & Butler, 2014; Kelley, et al., 1981; Kenny & Tarrant, 1987; Kent & Ewbank, 1986; Kent & Ewbank, 1986; Knowles, et al., 1997; Knowles, et al., 1999; Lay, et al., 1992a; Lensink, et al., 2000; Lensink, et al., 2001; Lensink, et al., 2001; Locatelli, et al., 1989; Lürzel, et al,. 2015a; Lürzel, et al,. 2015b; Mackenzie, et al., 1997; Maria, et al., 2004; Marques, et al., 2012; Mattiello, et al., 2002; McVeigh & Tarrant, 1982; Mellor, et al., 2002; Miranda de la Larna, et al., 2010; Miranda de la Larna, et al., 2012; Molony & Kent, 1997; Molony & Kent, 1997; Morisse, et al., 2000; Mormede, et al., 1982; Munksgaard, et al., 1999; Murata & Hirose, 1990; Murata & Hirose, 1991; Murata & Miyamoto, 1993; Murata, 1989; Murata, et al., 1987; Napolitano,et al., 2005; Odore, et al., 2004; Olsen, et al., 1980; Olsen, et al., 1981; Palme, et al., 2000; Panivivat, et al., 2004; Parker, et al., 2003; Parker, et al., 2004; Petherick, et al., 2009; Pettiford, et al., 2008; Pregel, et al., 2005; Prevedello, et al., 2012; Pritchard, et al., 2008; Raussi, 2005; Riondato, et al., 2008; Rulofson, et al., 1988; Schaefer, et al., 2007; Schaefer, et al., 2012; Schrader & Todt, 1998; Schrama, et al., 1996; Schwartzkopf-Genswein, et al., 2007; Scott & Christopherson, 1993; Smulders, et al., 2006; Stafford, et al., 2001; Stanger, et al., 2005; Stephens & Toner, 1975; Stewart, et al., 2007; Stewart, et al., 2010; Stewart, et al., 2010; Stockman, et al., 2011; Stockman, et al., 2013; Stockman, et al., 2012; Stull & McDonough, 1994; Svensson, et al., 2007; Tadich, et al., 2009a; Tadich, et al., 2009b; Tadich, et al., 2005; Tarrant, et al., 1988; Tarrant, et al., 1992; Todd, 1998; Todd, et al., 2000; Uetake, et al., 2009; Uetake, et al., 2011; Van de Water, et al., 2003a; Van de Water, et al., 2003b; Van de Water, et al., 2003b; van Reenen, et al., 2005; Veissier & le Neindre, 1988; Veissier, et al., 1998; Veissier, et al., 2001; Veissier, et al., 2001; Veissier, et al., 1997; Vermorel, 1989; Vermorel, et al., 1983; Warris, et al., 1994; Webster, et al., 2008; Wernicki, et al., 2006; Weschenfelder, et al., 2012; Wesselink, 1998; Wickham, et al., 2015; Willet & Erb, 1972; Zähner, et al., 2004.

Welfare Indicator	Number of Studies (%) n=253	Reference
Body temperature	48 (19.0)	Ahsan, et al., 2014; Barrier, et al., 2013; Bernardini, et al., 2015; Brown-Brandl, et al., 2005; Buckham Sporer, et al., 2008; Cafazzo, et al., 2012; Cramer & Stanton, 2015; Crookshank, et al., 1979; Diesch, 2002; Diesch, et al., 2004; Earley, et al., 2006; Earley & Murray, 2010; Earley & O'Riordan, 2006; Earley, et al., 2012; Ekpe & Christopherson, 2000; Fisher, et al., 2014; Giannetto, et al., 2011; Grigor, et al., 2001; Grigor, et al., 2007; Gupta, et al., 2007; Jacobson & Cook 1998; Kenny & Tarrant, 1987; Knowles, et al., 1999; McVeigh & Tarrant, 1982; Olsen, et al., 1981; Pettiford, et al., 2008; Pritchard, et al., 2008; Schaefer, et al., 2007; Schaefer, et al., 2012; Schrama, 1992a; Schrama, et al., 1993; Stafford, et al., 2001; Stewart, et al., 2007; Stockman, et al., 2011; Stockman, et al., 2013; Stull & McDonough, 1994; Svensson, et al., 2007; Todd, 1998; Todd, et al., 2000; Uetake, et al., 2009; Van de Water, et al., 2003a; Vermorel, 1989; Vermorel, et al., 1983; Webster, et al., 2008; Webster, et al., 1978; Wesselink, 1998; Wickham, et al., 2015; Willet & Erb, 1972; Zähner, et al., 2004
Heart Rate	38 (15.0)	Blaxter & Wood, 1951; Clapp, et al., 2015; Cockram, et al., 1999; Constable, et al., 1998; de Passillé, 1995; Færevik, et al., 2006; Giannetto, et al., 2011; Grigor, et al., 2001; Grigor, et al., 2004; Hopster & Blokhuis, 1994; Jacobson & Cook 1998; Jensen, et al., 1997; Kenny & Tarrant, 1987; Knowles, et al., 1997; Lauber, et al., 2006; Lay, et al., 1992a; Lensink, et al., 2001a; Lensink, et al., 2001b; Lürzel, et al,. 2015a; Lürzel, et al,. 2015b; McVeigh & Tarrant, 1982; Mohr, et al., 2002; Pritchard, et al., 2008; Raussi, 2005; Schwartzkopf-Genswein, et al., 2007; Stephens & Toner, 1975; Stewart, et al., 2010; Stewart, et al., 2010; Stockman, et al., 2011; Stockman, et al., 2013; Uetake, et al., 2009; Van de Water, et al., 2003a; Van de Water, et al., 2003b; van Reenen, et al., 2005; Waiblinger, et al., 2004; Wesselink, 1998; Wickham, et al., 2015; Zähner, et al., 2004
Post Mortem	34 (13.4)	Ahsan, et al., 2014; Becker, et al., 1989; Bokkers & Koene, 2001; Dalmau, et al., 2009; De la Fuente, et al., 2010; Fernandez, et al., 1996; González, et al., 2012b; Gottardo, et al., 2002; Grandin, 1998; Grigor, et al., 2004; Jarvis, et al., 1995; Jarvis, et al., 1996; Kirton & Paterson, 1973; Lensink, et al., 2000; Lensink, et al., 2001; Leruste, et al., 2012a; Llonch, et al., 2015; Mattiello, et al., 2002; McCausland, et al., 1977; Maria, et al., 2004; Miranda de la Larna, et al., 2010; Molony & Kent, 1997; Morisse, et al., 2000; Prevedello, et al., 2012; Sandström, 2009; Stafford, et al., 2001; Stockman, et al., 2012; Tarrant, et al., 1988; Tarrant, et al., 1992; Van de Water, et al., 2003b; Veissier, et al., 1998; Veissier, et al., 2001; Weschenfelder, et al., 2012; Wiepkema, et al., 1987; Xiccato, et al., 2002
Dehydration	19 (7.5)	Constable, et al., 1998; Diesch, 2002; Fazion, et al., 2005; Grigor, et al., 2001; Jarvis, et al., 1996; Jongman & Butler, 2014; Knowles, et al., 1997; Knowles, et al., 1999; Moore, et al., 2003; Parker, et al., 2003; Parker, et al., 2004; Pritchard, et al., 2008; Schaefer, et al., 2007; Schaefer, et al., 2012; Stafford, et al., 2001; Tadich, et al., 2009a; Tadich, et al., 2009b; Wesselink, 1998; Xiccato, et al., 2002

Welfare Indicator	Number of Studies (%) n=253	Reference
Diarrhoea	19 (7.5)	Abdelfattah, et al., 2013; Ahsan, et al., 2014; Cramer & Stanton, 2015; Gånheim, et al., 2007; Groutides & Michell, 1990; Hudson, et al., 1976; Kertz, et al., 1984; Llonch, et al., 2015; Mohr, et al., 2002; Morisse, et al., 2000; Prevedello, et al., 2012; Schaefer, et al., 2007; Schaefer, et al., 2012; Stull & McDonough, 1994; Svensson, et al., 2007; Thomas & Jordaan, 2013;Todd, 1998; Uetake, et al., 2011; Webster, et al., 1985
Coughing	14 (5.5)	Abdelfattah, et al., 2013; Bršćić, et al., 2012; Bršćić, et al., 2012; Cramer & Stanton, 2015; de Wilt, 1985; Leruste, et al., 2012a; Lidfors, 1993; Llonch, et al., 2015; Prevedello, et al., 2012; Schaefer, et al., 2007; Schaefer, et al., 2012; Smulders, et al., 2006; Svensson, et al., 2007; Takacova, et al., 2012
Lameness	14 (5.5)	Ahsan, et al., 2014; Bergman, et al., 2014; BRŠČIĆ, et al., 2011; Bršćić, et al., 2012; Dalmau, et al., 2009; Fregonesi & Leaver, 2001; González, et al., 2012b; Huxley, et al., 2004; Llonch, et al., 2015; Mülleder, et al., 2003; Napolitano,et al., 2005; Regula, et al., 2004; Takacova, et al., 2012; Winckler & Willen, 2001
Nasal Discharge	13 (5.1)	Abdelfattah, et al., 2013; Ahsan, et al., 2014; Bršćić, et al., 2012; Bršćić, et al., 2012; Cramer & Stanton, 2015; de Wilt, 1985; Leruste, et al., 2012a; Llonch, et al., 2015; Prevedello, et al., 2012; Schaefer, et al., 2007; Schaefer, et al., 2012; Svensson, et al., 2007; Takacova, et al., 2012
Injury	12 (4.7)	Ahsan, et al., 2014; Bergman, et al., 2014; BRŠČIĆ, et al., 2011; Candiani, et al., 2008; Dalmau, et al., 2009; Huxley, et al., 2004; Llonch, et al., 2015; Regula, et al., 2004; Smulders, et al., 2006; Stanković, et al., 2014; Takacova, et al., 2012; Uetake, et al., 2011
Mortality	12 (4.7)	Cave, et al., 2005; Dalmau, et al., 2009; González, et al., 2012b; Molony & Kent, 1997; Morisse, et al., 2000; Ortiz-Pelaez, et al., 2008; Peli, et al., 2016; Stull & McDonough, 1994; Thomas & Jordaan, 2013; Večerek, et al., 2006; Webster, et al., 1985; White, et al., 2009
Cleanliness	11 (4.3)	Fregonesi & Leaver, 2001; Gottardo, et al., 2002; Huxley, et al., 2004; Llonch, et al., 2015; Napolitano,et al., 2005; Panivivat, et al., 2004; Peli, et al., 2016; Regula, et al., 2004; Smulders, et al., 2006; Takacova, et al., 2012; Webster, et al., 1985
Respiration Rate	9 (3.6)	Blaxter & Wood, 1951; Brown-Brandl, et al., 2005; Bršćić, et al., 2012; Crookshank, et al., 1979; Dalmau, et al., 2009; Giannetto, et al., 2011; Leruste, et al., 2012a; Pritchard, et al., 2008; Willet & Erb, 1972
Disease	7 (2.8)	Stanković, et al., 2014; Schaefer, et al., 2007; Schaefer, et al., 2012; Svensson, et al., 2007; Thomas & Jordaan, 2013; Webster, et al., 1985; Wesselink, 1998
Ocular Discharge	7 (2.8)	Abdelfattah, et al., 2013; Ahsan, et al., 2014; Cramer & Stanton, 2015; de Wilt, 1985; Llonch, et al., 2015; Prevedello, et al., 2012; Takacova, et al., 2012
Demeanour	6 (5.4)	Llonch, et al., 2015; Prevedello, et al., 2012; Schaefer, et al., 2007; Schaefer, et al., 2012; Svensson, et al., 2007; Takacova, et al., 2012

Welfare Indicator	Number of Studies (%) n=253	Reference
Eyes	6 (5.4)	Constable, et al., 1998; Stafford, et al., 2001; Stewart, et al., 2007; Stewart, et al., 2008a; Stewart, et al., 2010; Takacova, et al., 2012
Hampered breathing	6 (5.4)	Brščić, et al., 2012; de Wilt, 1985; Prevedello, et al., 2012; Schaefer, et al., 2007; Schaefer, et al., 2012; Svensson, et al., 2007
Infrared Thermography	5 (2.0)	Schaefer, et al., 2007; Schaefer, et al., 2012; Stafford, et al., 2001; Stewart, et al., 2007; Stewart, et al., 2008a
Shivering	5 (2.0)	Dalmau, et al., 2009; González-Jimenez & Blaxter, 1962; Llonch, et al., 2015; Vermorel, 1989; Vermorel, et al., 1983
Number of teeth	4 (3.6)	Stafford, et al., 2001; Todd, 1998; Todd, et al., 2000; Wesselink, 1998
Faecal soiling	3 (1.2)	Kertz, et al., 1984; Moore, et al., 2003;Panivivat, et al., 2004
Morbidity	3 (1.2)	Schwartzkopf-Genswein, et al., 2007; Molony & Kent, 1997; White, et al., 2009
Skin irritation	3 (1.2)	Brščić, et al., 2012; Llonch, et al., 2015; Takacova, et al., 2012
Umbilical cord	3 (1.2)	Cramer & Stanton, 2015; Stafford, et al., 2001; Todd, 1998
Bursitis	2 (0.8)	Brščić, et al., 2011; Brščić, et al., 2012
Ear score	2 (0.8)	Abdelfattah, et al., 2013; Cramer & Stanton, 2015
Panting	2 (0.8)	Dalmau, et al., 2009; Llonch, et al., 2015
Vulvar Discharge	2 (0.8)	Ahsan, et al., 2014; Llonch, et al., 2015
Endoparasitism	1 (0.4)	Llonch, et al., 2015
Electroencephalogram	1 (0.9)	Hänninen, et al., 2005

Table 15.4 Animal-based indicators of behavioural interaction with the environment, other animals or humans (Domain 4) addressed in articles retrieved during the systematic mapping (n=253)

Welfare Indicator	Number of Studies (%) n=253	Reference
Lying	55 (21.7)	Abdelfattah, et al., 2013; Bokkers & Koene, 2001; Bokkers, et al., 2009; Cafazzo, et al., 2012; Candiani, et al., 2008; Cockram, et al., 1999; de Wilt, 1985; Fisher, et al., 2014; Fisher, et al., 1997; Fregonesi & Leaver, 2001; Garner, 2005; Grasso, et al., 1999; Grigor, et al., 2001; Grigor, et al., 2004; Haley, et al., 2000; Haley, et al., 2001; Hänninen, et al., 2005; Herskin, et al., 2004; Ibáñez, et al., 2002; Ishiwata & Kariya, 2010; Jarvis, et al., 1996; Jongman & Butler, 2014; Kent & Ewbank, 1986; Kent & Ewbank, 1986; Knowles, et al., 1999; Lensink, et al., 2001; Llonch, et al., 2015; Margerison, et al., 2003; Mattiello, et al., 2002; Mellor, et al., 1991; Mogensen, et al., 1997; Mohr, et al., 2002; Molony & Kent, 1997; Mülleder, et al., 2003; Munksgaard, et al., 1999; Panivivat, et al., 2004; Prevedello, et al., 2012; Raussi, 2005; Regula, et al., 2004; Schrama, et al., 1993; Schrama, et al., 1995; Schwartzkopf-Genswein, et al., 2007; Stull & McDonough, 1994; Tapkı, et al., 2006; Tarrant, et al., 1992; Todd, 1998; Uetake, et al., 2011; Van de Water, et al., 2003a; Veissier, et al., 2001; Veissier, et al., 1989; Vermorel, 1989; Webb, et al., 2012; Webster, et al., 2008; Westerath, et al., 2006; Zähner, et al., 2004
Drink/Chew/ruminate	49 (19.4)	Abdelfattah, et al., 2013; Bokkers & Koene, 2001; Bokkers, et al., 2009; Brown-Brandl, et al., 2005; Budzynska & Weary, 2008; Cafazzo, et al., 2012; Candiani, et al., 2008; Cockram, et al., 1999; de Wilt, 1985; Dellmeier, et al., 1990; Duve, et al., 2012; Fisher, et al., 1997; Fregonesi & Leaver, 2001; Gottardo, et al., 2002; Grasso, et al., 1999; Grigor, et al., 2001; Grigor, et al., 2004; Haley, et al., 2001; Herskin, et al., 2004; Ibáñez, et al., 2002; Ishiwata & Kariya, 2010; Jarvis, et al., 1996; Jasper, et al., 2008; Jongman & Butler, 2014; Kent & Ewbank, 1986; Knowles, et al., 1999; Lidfors, 1993; Margerison, et al., 2003; Mattiello, et al., 2002; Miller, et al., 2006; Molony & Kent, 1997; Morisse, et al., 2000; Munksgaard, et al., 1999; Panivivat, et al., 2004; Peli, et al., 2016; Prevedello, et al., 2012; Pritchard, et al., 2008; Raussi, 2005; Reefman, et al., 2009; Rushen & de Passillé, 1995; Schwartzkopf-Genswein, et al., 2007; Tapkı, et al., 2006; Veissier, et al., 1998; Veissier, et al., 1989; Veissier, et al., 1997; Webb, et al., 2012; Webster, et al., 2008; Westerath, et al., 2006.
Standing	46 (18.2)	Blaxter & Wood, 1951; Boissy, et al., 2001; Budzynska & Weary, 2008; Cafazzo, et al., 2012; Candiani, et al., 2008; de Wilt, 1985; Dellmeier, et al., 1990; Earley & Murray, 2010; Færevik, et al., 2006; Fregonesi & Leaver, 2001; Garner, 2005; Grasso, et al., 1999; Grigor, et al., 2004; Haley, et al., 2000; Haley, et al., 2001; Herskin, et al., 2004; Hopster & Blokhuis, 1994; Ibáñez, et al., 2002; Ishiwata & Kariya, 2010; Jarvis, et al., 1996; Jensen, et al., 1997; Knowles, et al., 1997; Knowles, et al., 1999; Margerison, et al., 2003; Mattiello, et al., 2002; Mellor, et al., 1991; Mülleder, et al., 2003; Munksgaard, et al., 1999; Panivivat, et al., 2004; Raussi, 2005; Regula, et al., 2004; Schrama, et al., 1993; Schrama, et al., 1995; Schwartzkopf-Genswein, et al., 2007; Stull & McDonough, 1994; Tapkı, et al., 2006; Todd, 1998; Uetake, et al., 2011; Van de Water, et al., 2003a; Veissier, et al., 2001; Veissier, et al., 1989; Vermorel, 1989; Waiblinger & Menke, 2003; Waiblinger, et al., 2004; Webb, et al., 2012; Webster, et al., 2008

Welfare Indicator	Number of Studies (%) n=253	Reference
Movement	39 (15.4)	Boissy, et al., 2001; Bourguet, et al., 2010; de Passillé, 1995; Dellmeier, et al., 1990; Duve, et al., 2012; Færevik, et al., 2006; Grasso, et al., 1999; Grigor, et al., 2004; Hopster & Blokhuis, 1994; Hultgren, et al., 2014; Ibáñez, et al., 2002; Ishiwata & Kariya, 2010; Jarvis, et al., 1996; Jasper, et al., 2008; Jensen & Kyhn, 2000; Jensen, 1999; Jensen, et al., 1997; Jensen, et al., 2001; Krachun, et al., 2010; Lensink, et al., 2001; Lürzel, et al,. 2015b; Margerison, et al., 2003; Miller, et al., 2006; Napolitano,et al., 2005; Raussi, 2005; Sandström, 2009; Schwartzkopf-Genswein, et al., 2007; Tapkı, et al., 2006; Tarrant, et al., 1992; Uetake, et al., 2011; Van de Water, et al., 2003b; Van Reenan, et al., 2004; van Reenen, et al., 2005; Veissier, et al., 1998; Veissier, et al., 2001; Veissier, et al., 1989; Veissier, et al., 1997; Waiblinger, et al., 2004; Weschenfelder, et al., 2012
Oral	33 (13.0)	Abdelfattah, et al., 2013; Blaxter & Wood, 1951; Bokkers & Koene, 2001; Bokkers, et al., 2009; Brščić, et al., 2012; Cafazzo, et al., 2012; de Wilt, 1985; Dellmeier, et al., 1990; Duve, et al., 2012; Garner, 2005; Gottardo, et al., 2002; Ishiwata & Kariya, 2010; Jasper, et al., 2008; Kooijman, et al., 1991; Leruste, et al., 2014; Lidfors, 1993; Lürzel, et al,. 2015a; Margerison, et al., 2003; Mattiello, et al., 2002; Miranda de la Larna, et al., 2012; Molony & Kent, 1997; Mülleder, et al., 2003; Munksgaard, et al., 1999; Panivivat, et al., 2004; Raussi, 2005; Rushen & de Passillé, 1995; Smulders, et al., 2006; Van de Water, et al., 2003a; Veissier, et al., 1998; Veissier, et al., 1989; Veissier, et al., 1997; Webb, et al., 2012; Wiepkema, et al., 1987
Vocalising	25 (9.9)	Bourguet, et al., 2010; Budzynska & Weary, 2008; Dalmau, et al., 2009; de Passillé, 1995; Dellmeier, et al., 1990; Færevik, et al., 2006; Grandin, 1998b; Grandin, 1998; Grandin, 2001; Hemsworth, et al., 2011; Hultgren, et al., 2014; Jasper, et al., 2008; Jensen, et al., 1997; Lauber, et al., 2006; Lay, et al., 1992a; Maria, et al., 2004; Napolitano,et al., 2005; Sandström, 2009; Schrader & Todt, 1998; Van de Water, et al., 2003a; Van Reenan, et al., 2004; van Reenen, et al., 2005; Watts, 2000; Weschenfelder, et al., 2012; Willet & Erb, 1972
Animal Handling	22 (8.7)	Bokkers & Koene, 2001; Garner, 2005; González, et al., 2012b; Grandin, 1998b; Grandin, 1998; Hemsworth, et al., 2011; Hultgren, et al., 2014; Jago, et al., 1999; Lensink, et al., 2000; Lensink, et al., 2000; Lensink, et al., 2001; Lensink, et al., 2003; Lensink, et al., 2001; Leruste, et al., 2012b; Lürzel, et al,. 2015a; Lürzel, et al,. 2015b; Regula, et al., 2004; Rousing, et al., 2005; Schütz, et al., 2012; Stanković, et al., 2014; Van Reenen, et al., 2004; Veissier, et al., 1998
Eliminating	20 (7.9)	de Passillé, 1995; Hultgren, et al., 2014; Ishiwata, et al., 2008; Jago, et al., 1999; Jensen, et al., 1997; Kenny & Tarrant, 1987; Kertz, et al., 1984; Lauber, et al., 2006; Lensink, et al., 2000; Lürzel, et al,. 2015b; Maria, et al., 2004; Napolitano,et al., 2005; Parker, et al., 2003; Schrama, 1992a; Schrama, et al., 1993; Smulders, et al., 2006; Tapkı, et al., 2006; Van de Water, et al., 2003a; Van de Water, et al., 2003b; Van Reenen, et al., 2005
Sniffing/Licking	20 (7.9)	Boissy, et al., 2001; de Passillé, 1995; de Wilt, 1985; Duve, et al., 2012; Herskin, et al., 2004; Jensen & Kyhn, 2000; Jensen, 1999; Jensen, et al., 1997; Jensen, et al., 2001; Lauber, et al., 2006; Mattiello, et al., 2002; Miranda de la Larna, et al., 2012; Raussi, 2005; Sandström, 2009; Tarrant, et al., 1988; Veissier, et al., 1998; Veissier, et al., 1997; Veissier, et al., 2001; Webb, et al., 2012; Westerath, et al., 2006

Welfare Indicator	Number of Studies (%) n=253	Reference
Grooming	19 (7.5)	Abdelfattah, et al., 2013; Bokkers & Koene, 2001; Bokkers, et al., 2009; Dellmeier, et al., 1990; Grasso, et al., 1999; Herskin, et al., 2004; Ishiwata & Kariya, 2010; Lürzel, et al,. 2015b; Margerison, et al., 2003; Mattiello, et al., 2002; Miranda de la Larna, et al., 2012; Molony & Kent, 1997; Munksgaard, et al., 1999; Panivivat, et al., 2004; Raussi, 2005; Schütz, et al., 2012; Veissier, et al., 1998; Veissier, et al., 1997; Webb, et al., 2012
Playing	17 (6.7)	Abdelfattah, et al., 2013; Blaxter & Wood, 1951; Duve, et al., 2012; Ishiwata & Kariya, 2010; Jago, et al., 1999; Jensen & Kyhn, 2000; Jensen, et al., 1998; Jensen, et al., 2001; Kenny & Tarrant, 1987; Krachun, et al., 2010; Llonch, et al., 2015; Lürzel, et al,. 2015a; Mintline, et al., 2013; Mülleder, et al., 2003; Schütz, et al., 2012; Smulders, et al., 2006; Tapkı, et al., 2006
Exploration	15 (5.9)	Cafazzo, et al., 2012; Candiani, et al., 2008; Dellmeier, et al., 1990; Færevik, et al., 2006; Hultgren, et al., 2014; Ishiwata & Kariya, 2010; Kenny & Tarrant, 1987; Lauber, et al., 2006; Lürzel, et al,. 2015b; Panivivat, et al., 2004; Schütz, et al., 2012; Tarrant, et al., 1988; Tarrant, et al., 1992; Veissier, et al., 2001; Westerath, et al., 2006
Idle	15 (5.9)	Bokkers, et al., 2009; de Passillé, 1995; Grasso, et al., 1999; Hultgren, et al., 2014; Huxley, et al., 2004; Jago, et al., 1999; Jensen, et al., 2001; Molony & Kent, 1997; Munksgaard, et al., 1999;Raussi, 2005; Sandström, 2009; Veissier, et al., 1998; Veissier, et al., 1989; Veissier, et al., 1997; Waiblinger, et al., 2004
Mounting	15 (5.9)	Bokkers, et al., 2009; Dellmeier, et al., 1990; Duve, et al., 2012; Grigor, et al., 2004; Jarvis, et al., 1995; Jarvis, et al., 1996; Jensen, et al., 2001; Kenny & Tarrant, 1987; Maria, et al., 2004; Miranda de la Larna, et al., 2012; Sandström, 2009; Tarrant, et al., 1988; Van de Water, et al., 2003b; Veissier, et al., 1998; Webb, et al., 2012
Slipping/falling	15 (5.9)	Bokkers, et al., 2009; Dalmau, et al., 2009; Dellmeier, et al., 1990; Grandin, 1998; Grigor, et al., 2004; Hultgren, et al., 2014; Jacobson & Cook, 1998; Jarvis, et al., 1995; Jarvis, et al., 1996; Maria, et al., 2004; Sandström, 2009; Tarrant, et al., 1988; Tarrant, et al., 1992; Van de Water, et al., 2003b; Weschenfelder, et al., 2012
Aggressive	14 (5.5)	Abdelfattah, et al., 2013; Cafazzo, et al., 2012; Candiani, et al., 2008; Fisher, et al., 1997; Grasso, et al., 1999; Llonch, et al., 2015; Margerison, et al., 2003; Miranda de la Larna, et al., 2012; Raussi, 2005; Sandström, 2009; Smulders, et al., 2006; Tarrant, et al., 1988; Tarrant, et al., 1992; Veissier, et al., 2001
Butting	12 (4.7)	Bokkers, et al., 2009; de Wilt, 1985; Duve, et al., 2012; Fregonesi & Leaver, 2001; Jago, et al., 1999; Jarvis, et al., 1995; Jarvis, et al., 1996; Jensen, et al., 2001; Kenny & Tarrant, 1987; Miranda de la Larna, et al., 2012; Mülleder, et al., 2003; Raussi, 2005; Rushen & de Passillé, 1995; Tarrant, et al., 1988; Veissier, et al., 1998; Waiblinger, et al., 2004; Webb, et al., 2012
Kicking	10 (4.0)	Bourguet, et al., 2010; Hultgren, et al., 2014; Jensen, et al., 2001; Lensink, et al., 2001; Lensink, et al., 2001; Miranda de la Larna, et al., 2012; Molony & Kent, 1997; Napolitano,et al., 2005; Waiblinger, et al., 2004; Webb, et al., 2012

Welfare Indicator	Number of Studies (%) n=253	Reference
Avoidance	9 (3.6)	Lay, et al., 1992a; Lürzel, et al,. 2015a; Lürzel, et al,. 2015b; Mülleder, et al., 2003; Napolitano,et al., 2005; Schütz, et al., 2012; Waiblinger & Menke, 2003; Waiblinger, et al., 2004; Windschnurer, et al., 2008
Qualitative Behaviour Assessment	9 (3.6)	Andreasen, et al., 2013; Bršćić, et al., 2012; Ellingsen, et al., 2014; Llonch, et al., 2015; Stockman, et al., 2011; Stockman, et al., 2013; Stockman, et al., 2012; Wemelsfelder, et al., 2000; Wickham, et al., 2015
Resting	9 (3.6)	Dalmau, et al., 2009; Hänninen, et al., 2003; Hänninen, et al., 2005; Ishiwata, et al., 2008; Mogensen, et al., 1997; Molony & Kent, 1997; Munksgaard, et al., 1999; Tapkı, et al., 2006; Zähner, et al., 2004
Jump	7 (2.8)	de Passillé, 1995; Dellmeier, et al., 1990; Duve, et al., 2012; Krachun, et al., 2010; Maria, et al., 2004; Sandström, 2009; Webb, et al., 2012;
Active	6 (2.4)	Blaxter & Wood, 1951; Bokkers, et al., 2009;Molony & Kent, 1997; Veissier, et al., 2001; Vermorel, 1989; Vermorel, et al., 1983;
Agonistic	6 (2.4)	Fregonesi & Leaver, 2001; Kenny & Tarrant, 1987; Mülleder, et al., 2003; Raussi, 2005; Tarrant, et al., 1988; Waiblinger, et al., 2004
Social	6 (5.4)	Bokkers & Koene, 2001; Duve, et al., 2012; Færevik, et al., 2006; Fisher, et al., 1997; Grasso, et al., 1999; Mattiello, et al., 2002; Miranda de la Larna, et al., 2012; Mülleder, et al., 2003; Veissier, et al., 1998; Veissier, et al., 2001
Baulk	5 (2.0)	Jago, et al., 1999; Maria, et al., 2004; Sandström, 2009; Van de Water, et al., 2003b; Weschenfelder, et al., 2012
Rubbing	5 (2.0)	de Wilt, 1985; Ishiwata, et al., 2008; Miranda de la Larna, et al., 2012; Webb, et al., 2012; Westerath, et al., 2006
Withdrawal distance	5 (2.0)	Lauber, et al., 2006; Lensink, et al., 2000; Lensink, et al., 2001; Mülleder, et al., 2003; Rousing, et al., 2005
Scratching	4 (1.6)	Bokkers, et al., 2009; de Wilt, 1985; Miranda de la Larna, et al., 2012; Veissier, et al., 1997
Stereotypies	4 (1.6)	Llonch, et al., 2015; Miranda de la Larna, et al., 2012; Smulders, et al., 2006; Wiepkema, et al., 1987
Turn	3 (1.2)	Maria, et al., 2004; Sandström, 2009; Webb, et al., 2012
Escape	2 (0.8)	Lay, et al., 1992a; Lürzel, et al,. 2015b
Head shaking	2 (0.8)	Waiblinger, et al., 2004; Webb, et al., 2012
Nose licking	2 (0.8)	Bokkers, et al., 2009; de Wilt, 1985;

Welfare Indicator	Number of Studies (%) n=253	Reference
Stretching	2 (0.8)	Bokkers, et al., 2009; de Wilt, 1985
Struggling	2 (0.8)	Duve, et al., 2012; Hultgren, et al., 2014
Comfort behaviour	1 (0.4)	Bokkers & Koene, 2001
Compression	1 (0.4)	Bokkers, et al., 2009
Crowding	1 (0.4)	Hultgren, et al., 2014
Head lifting	1 (0.4)	Bourguet, et al., 2010
Learning	1 (0.4)	Lauber, et al., 2006
Loading/Unloading time	1 (0.9)	Maria, et al., 2004
Non-agonistic	1 (0.4)	Raussi, 2005
Positive	1 (0.4)	Llonch, et al., 2015;
Return time	1 (0.4)	Lauber, et al., 2006
Tail flicking	1 (0.4)	Lürzel, et al,. 2015b
Vigour	1 (0.4)	Todd, 1998

Appendix 16: Group (pen) level observations of calves in lairage

Group Level Observations

Pen Number [/]

Time of Arrival [ ] **Time of observations** [ ]

Pen location [ ]

Dimension of pens Length [ ] x Width [ ]

Shelter provided Roof Walls

Temperature [ ]

Wind speed [ ]

Number of animals in pen [ ]

Number of animals lying in the pen [ ] **Standing** [ ]

Behavioural Observations

	Number of animals per group	% of group
Shivering		
Panting		
Huddling		
Oral Behaviours		
Vocalisation		
Head tilting		
Head shaking		

Behaviours demonstrating [ ]

Health Observations

	Number of animals per group	% of group
Coughing		
Hampered respiaration		
Severe Ocular discharge		
Severe Nasal discharge		

Faecal Soiling

	Number of animals per group	% of group
No		
Moderatly Dirty		
Extremely Dirty		

Injury	# of animals	% of group	
0			No visual wounds/injuries
1			Hairloss
2			Moderate swelling and/or superficial wound
3			Minor cut through skin or obvious swelling
4			Wound through skin with deeper damage
5			Injury resulting in loss of function

Walk-through completed Y / N (only if there are calves lying down)

Numer of calves lying immediatedly prior to walk-through

Number of calves that got up when observer first entered the pen

Number of calves that get up during systematic walk

Number of calves that get up when approached within 0.5m (after walk-through)

Number of calves that did not get up (non-ambulatory)

Exhaustion?

Number of calves that return to lying 5minutes after walk-through

Comment on position lying

Water source working Y / N

Comments and Notes

Diarrhoea

Appendix 17: Individual level observations and measurements of calves in lairage

Individual Level Observations

Pen Number /   Animal Number /

Calf standing Y / N   If no, lying position

Indicators

Shivering

Yes	
No	

Panting

Normal respiration		20-40 breaths per minute
Mild Heat Stress		Closed mouth breathing w/ respiration elevated over 20-40 breaths/min
Panting		Open mouth breathing with respiration elevated over 40 breaths/min

Respiration Rate breaths per minute

Hampered respiation

Coughing

Vocalisation Vocalising? Y / N

If yes Rate over 2 minutes

Duration

Oral Behaviours Y / N

Manipulating an object		biting, suckling, licking
Manipulating a calf		cross-suckling
Tongue Playing		
Other		

Head tilting

Head shaking

Faecal Soiling

No	
Moderatly Dirty	
Extremely Dirty	

Injury

0		No visual wounds/injuries
1		Hairloss
2		Moderate swelling and/or superficial wound where skin not perforated
3		Minor cut through skin or obvious swelling
4		Wound through skin with damage to deeper tissues
5		Injury resulting in loss of function

Ocular discharge present Y / N

If yes: Mild   Severe

Nasal discharge present Y / N

If yes: Mild   Severe

Dehydration	Time for skin to return to normal after skin tent:			
General demeanor	Bright	Tired	Weak	
Navel	Wet	Raw	Dry	
Eyes	Bright	Dull	Closed	
Ears	Forwards	Back	Alert	
Coat	Dry	Clean	Wet	Dirty
Hooves	Strong	Soft/undeveloped		

Sex

Breed

Comments and Notes

Diarrhoea
Lesions
Lameness
Ectoparasitism
Mucous Membranes