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A Systematic Review on Management Practices Affecting Welfare in Male Calves: A Five Domains Model Approach

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Abstract

Veal calf welfare is of critical concern, as various management practices can contribute significantly to negative effects on health and welfare outcomes. The present review aimed to systematically collect and analyze the available evidence regarding the management strategies affecting the well-being of male calves worldwide, according to the five domains model. A systematic search was conducted for studies published until March 31, 2023, in five electronic databases (i.e., OVID®/MEDLINE, PubMed®, SciELO, Redalyc, Web of Science™). Only articles published in peer-reviewed journals were considered, and inclusion and exclusion criteria were established a priori and maintained throughout the systematic process. Thirty-six articles underwent the final inclusion criteria. All were published in English, in 15 journals, and between 1997 and 2023. The relevant articles reported management practices according to each of the five domains. Management strategies with a negative effect on calf welfare included inadequate feeding of high-optimal colostrum within a few hours of birth, lack of a colostrum management program, dehorning/castration without local anesthesia or analgesia, and long transportation of <14-day-old calves. Opportunities to improve male calf welfare included management practices such as ad libitum feeding, early provision of solid feed, socially grouped housing, adequate hutch space, and pain management during routine productive procedures. None of the studies were directly related to domain 5 (mental status). In general, there has been an increase in the number of studies on male calf welfare over time. Several management strategies can be considered or improved around new policies and management programs in male calf populations in consideration of the five domain approach.

Keywords: Animal well-being, five domains, management strategy, systematic review, veal calves

Introduction

The growing global demand for dairy products presents an opportunity for both developed and developing nations to enhance the nutrition, health, income, and livelihoods of millions of individuals. Dairy farming serves as a vital system that contributes significantly to global food security (Adesogan & Dahl, 2020; García et al., 2019). In this context, as the dairy industry expands and its significance for food security rises, dairy production systems raise concerns regarding animal welfare, particularly in the rearing of male dairy calves (i.e., veal calves, surplus calves, or bobby calves), which have been identified as being at high welfare risk (Shivley et al., 2019). Indeed, in regions lacking a developed industry for the rearing of male calves, most male calves are transported over long distances to be slaughtered within the first few days of life (Maher et al., 2021).

From a historical standpoint, male calves have been subject to negative stigma and social concerns regarding animal welfare (Creutzinger et al., 2021). Various management practices exacerbate these issues, including the immediate removal of calves from dairy farms after birth (Busch et al., 2017), prolonged transportation with stops at auction markets or assembly stations before reaching their destination farms (Creutzinger et al., 2022), intensive housing and rearing protocols (Peña et al., 2016), restricted feeding levels (Azevedo et al., 2016), and other treatments administered during the early weeks of the calf's life, all contributing to elevated morbidity and mortality rates.

Considerable attention has been directed toward the care and handling of newborn dairy calves in recent times, including aspects such as colostrum management and pain relief. However, there has been relatively limited research focusing on the care and management of male calves, possibly due to their lower value to the dairy industry compared to female counterparts (Reed et al., 2022; Shivley et al., 2019). For instance, Shivley et al. (2019) observed disparities in the management of male and female calves within the same farm, with many male calves often undergoing dehorning and castration procedures without the use of pain mitigation measures.

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Animal welfare refers to the physical and mental well-being of an animal, encompassing the conditions in which it lives and ultimately perishes (Keeling et al., 2019). There is an increasing concern for animal welfare, especially concerning husbandry and transportation practices, aimed at ensuring that herds adhere to welfare standards (Bozzo et al., 2021). Nowadays, the protection of animal welfare has become a prominent aspect of public policy in numerous countries (Keeling et al., 2019).

Given the heightened risk to the welfare of male calves, it is crucial to investigate the practices impacting them, particularly considering the "one welfare" concept. This concept emphasizes that inadequate animal welfare not only impacts production systems but also has adverse effects on human welfare (Tarazona et al., 2019). The five domains model proposed by Mellor et al. (2020) is a useful tool for assessing animal welfare in the dairy industry. Using examples of positive and negative effects of humans on animals and positive experiences of animals in human–animal interactions. This model offers a framework for assessing the significance of various rearing conditions on animal welfare, thereby presenting opportunities for enhancing welfare standards, by defining five domains: domain 1, nutrition (water and deprivation, and malnutrition); domain 2, environment (physical and atmospheric challenges); domain 3, health (disease, injury, and functional impairment); domain 4, behavioral interactions (behavioral and/or interactive movement restrictions); and domain 5, mental status (thirst, hunger, anxiety, fear, pain, distress).

Therefore, given the lack of information on male calf welfare, we aimed to systematically collect and analyze the available evidence regarding the management strategies affecting the well-being of male calves worldwide, according to the five domains model.

Materials and Methods

This systematic review (SR) was planned, conducted, and reported in compliance with the PRISMA standards (Page et al., 2021). The study question, method of conducting the literature search, study inclusion/non-inclusion criteria, and checklists for conducting relevance screening, baseline characterization, methodological assessment, and data extraction of relevant primary research were all conducted according to an a priori established and pre-tested SR protocol.

Search Strategy

What management practices affect male calf well-being was our specific research question, and therefore, the study topic that needed to be identified and assessed. The initial search took place on March 31, 2023.

Five search databases (i.e., OVID®/MEDLINE, PubMed®, SciELO, Redalyc, Web of Science™) were searched. The topic was divided into components and the search terms used to find relevant studies on the platforms were: (management OR handling OR control OR care OR rearing OR guidance) AND (strategies OR plan* OR approach OR approaches OR challenge* OR practice* OR strategy OR program* OR scheme* OR method* OR planning OR procedure*) AND (well-being OR welfare OR wellness) AND (calves OR calf OR "young bull" OR Veal* OR "young cow" OR "baby cow" OR "baby bull" OR yearling* OR neonate OR neonatal) AND (dairy OR dairies OR livestock OR cattle).

Eligibility Screening

The inclusion criteria solely encompassed original articles published in peer-reviewed journals and written in English, Portuguese, French, or Spanish. Neither the publication year nor the country of origin was a restrictive factor.

The initial citation selection process relied on information provided in the titles, conducted by two of the authors. Citations were chosen based on their potential relevance to the study topic. Subsequently, two authors screened the list of acceptable citations using their abstracts, while adhering to the inclusion and exclusion criteria established during the title screening phase. Following this, two authors thoroughly examined the full text of the remaining citations to ensure they contained pertinent data to address the research question. Kappa coefficients were calculated for each of the three selection stages to estimate agreement. The materials, methods, and results sections of each full text were scrutinized in detail. In addition, articles were considered eligible if they involved calves up to 60 days old as the study population, presented management practices related to one or more of the five domains, and reported explicit impacts (i.e., measurable effects). Any conflicts were resolved through consensus among the authors.

As a final step, two of the authors conducted a manual search of the references cited in the relevant articles identified during full-text screening (a process known as snowballing) to identify additional published sources.

Data Extraction

Following the compilation of all relevant publications, a descriptive summary was provided that considered the information on management strategies affecting the well-being in male calves, according to each one of the five domains, and other pertinent findings on the topic (i.e., country, age and breed of the male calves studied, population size, study design, type of production system, management strategy of analysis, and conclusions).

Results

The electronic search, combining results from all search engines and after deduplication, yielded 8016 eligible citations possibly associated with the subject of this SR. The citations to be reviewed were published between 1949 and 2023. After reading the titles, 7743 were considered unrelated (agreed by two authors agreed). The final number of citations by title screening was 273 (retained by at least one reviewer). After reading the abstracts of the articles, 119 were excluded (by both authors) and 154 original articles remained for the full-text review. Twenty-four articles were completely reviewed by full-text and kept for data extraction, after dismissing 137 articles at this phase. The snowballing strategy was then applied through the reference lists of the 24 definitive articles and 38 citations were retained after title screening. After abstract screening, 24 citations were retained. The final selection of articles from the snowballing method held 12 results. The final number of articles that met the eligibility criteria and were therefore included in the qualitative synthesis was 36. The file with the systematic process of collection and selection of citations is available as supplementary material (SM1). Figure 1 describes the SR protocol and the selection of relevant articles.

All articles were written in English. The first relevant article was published in 1997 and the most recent in 2023. Relevant citations

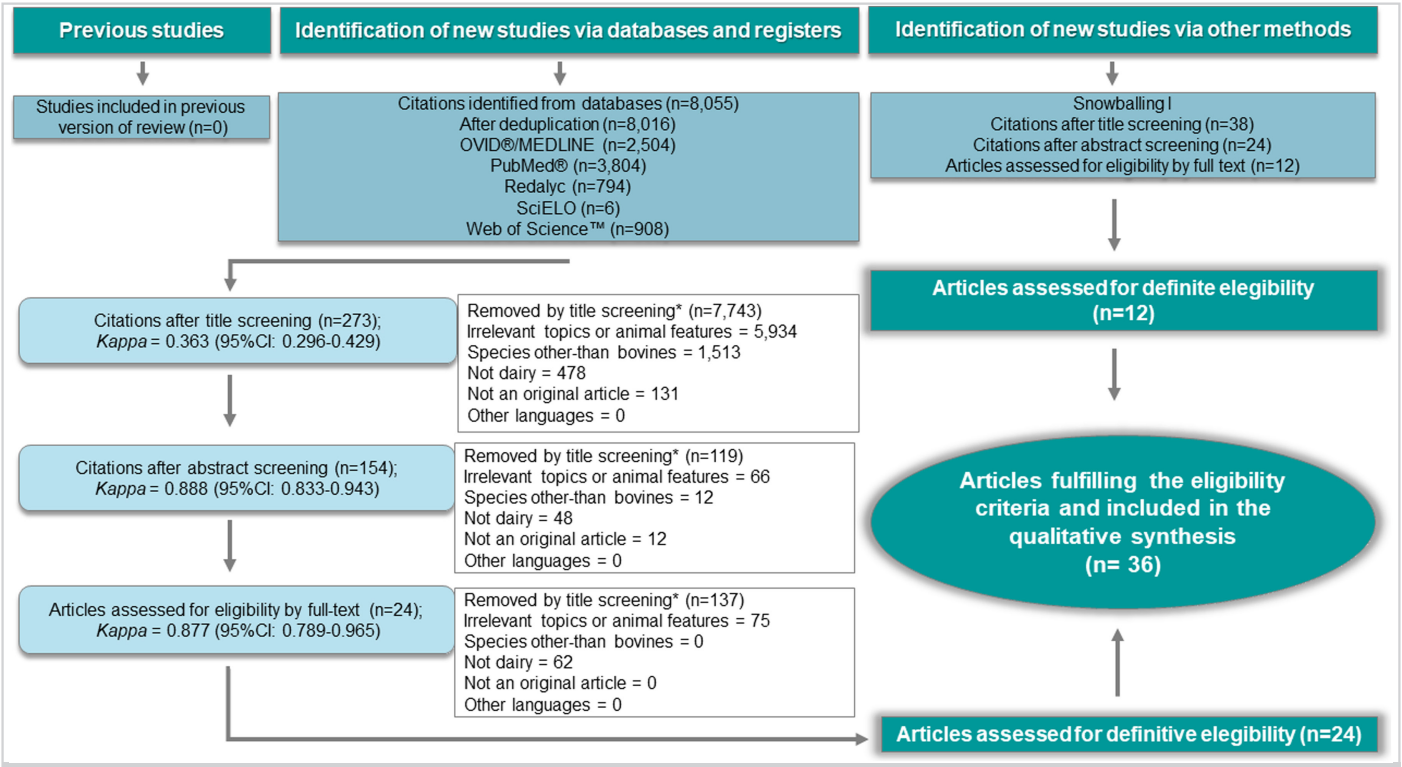

Figure 1.
Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Chart, Describing the Progress of the Citations through the Systematic Review.

were published in 15 different journals. Canada and the United States were the countries where most of the studies were conducted (9/36, respectively). Other countries where male calf's management practices were evaluated included Australia (2/36), France (2/36), Germany (2/36), Hungary (2/36), Ireland (1/36), Italy (1/36), the Netherlands (3/36), Norway (1/36), Portugal (1/36), Spain (1/36), and Switzerland (3/36). The calves ranged from 0 (newborn) to 109 days of age. A total of 8272 male calves were placed under one or more management practices.

Tables 1–4 present the information on management strategies affecting the well-being in male calves, according to the first four of the five domains. None of the practices evaluated and reported in the studies contained in the relevant articles were directly related to domain 5 (mental status).

A total of 12 articles evaluated practices related to domain 1 (nutrition) (Table 1) in male-dairy calves and their influence on welfare. The two main management practices were colostrum and nutritional management during the rearing period. Regarding colostrum administration, different practices can be highlighted as the method of such administration. In relation to feeding management practices, different studies evaluated the frequency, method, and nutritional value of different types of feeds for male dairy calves.

Nine articles were selected for domain 2 (environment) (Table 2). The practices evaluated included housing and transport conditions. In the first case, the evaluation of the hutches space was frequent (Calvo-Lorenzo et al., 2016; Hulbert et al., 2019), and the presence of shade in housing conditions (Kovács et al., 2018). The transport length was a common practice evaluated (Fisher et al., 2014; Marcato et al., 2022a; 2022b; Wilson et al., 2020).

A total of eight articles reported practices related to tissue injuries in male calves. Castration and dehorning were the most evaluated topics related to domain 3 (health) (Table 3). The effect of castration at different ages on pain and stress variables (e.g., cortisol levels, healing) was reported. Castration was also evaluated in terms of methods such as using a rubber ring, Burdizzo clamp, and surgical approach. For both castration and dehorning, results were reported using unimodal or multimodal analgesia for pain management.

Regarding domain 4 (behavioral interactions) (Table 4), eight articles were reviewed. In general, studies explored management strategies such as regrouping (Veissier et al., 2001), the rearing type (i.e., grouped, individual; Costa et al., 2014; 2015), the calf-to-calf contact (Veissier et al., 1997), and cow–calf contact (Grøndahl et al., 2007; Daros et al., 2014; Mac et al., 2023; Webb et al., 2022).

Discussion

Based on the findings and acknowledging that the results were explicitly linked to the affected animal welfare domain, we have opted to present the results utilizing the five domains model proposed by Mellor et al. (2020). This approach enables us to differentiate between the physical and functional factors that contribute to the well-being of male calves and the resultant overall mental state. By adopting this framework, we can systematically outline methods aimed at enhancing the welfare of male calves in a targeted manner.

Table 1.

Information on Management Strategies Affecting the Well-being in Veal Calves (Domain 1: Nutrition)

Colostrum Management							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Chigerwe et al. (2008)	United States	0-2 d	Holstein	120	Experimental, randomly allocated	Colostrum feeding (amount)	Administration of at least 150-200 g of colostral IgG and 3 L of colostrum were required for adequate passive transfer, using an oroesophageal tube within 2 h after birth
Stilwell & Carvalho (2011)	Portugal	0-15 d	Holstein	97	Descriptive cross-sectional	Colostrum feeding	Quick test was useful in recognizing calves susceptible to diseases. Morbimortality owed to infectious diseases were higher in the negative group (no quick test used)
Lora et al. (2018)	Italy	1-5 d	Holstein	108	Cross-sectional	Colostrum feeding (time, amount, and quality)	Holstein calves had a higher FTPI risk compared with crossbreds and females' calves. Every additional CMS point increased Ig concentration in 1.53 g/L. Veal calves needed 2.5 L of > 87.6 g/L Ig concentration of colostrum in less than 1 h after birth
Renaud et al. (2018a)	Canada	1-10 d	Holstein	75	Cross-sectional	Colostrum feeding, milk source, and time to colostrum collection	Colostrum feeding method other than by nipple bottle, using a tube feeder or bucket, bedding calves on wood shavings, or chopped straw, and not routinely veterinary visits were identified as risk factors associated to a higher mortality
Gerbert et al. (2018)	Germany	0-11 w	Holstein	64	Experimental, not randomly allocated	Colostrum and MR feeding (method)	*Ad libitum* MR feeding increased MR intake, MR intake per meal, sucking rate, and BW but decreased the number of unpaid visits and the amount of concentrate consumed when compared to restrictive feeding. Butyrate boosted MR intake per meal while decreasing the sucking rate
Fischer et al. (2018)	Canada	0-10 d	Holstein	27	Experimental randomly allocated	Colostrum feeding (moment of administration)	Administration of colostrum 6-12 h after birth decreases IgG absorption compared with its administration immediately after. Postponing colostrum feeding in 12 hours of birth decreases passive IgG transport and may delay gut´s bacterial colonization, making calves susceptible to disease during the pre-weaning period
Renaud et al. (2020)	Canada	1-7 d	Not specified	580	Descriptive retrospective	Colostrum feeding (frequency)	Variables associated with FTPI included being male, delivery by a hard pull, receiving first colostrum administration from a bottle combination followed by an esophageal feeding tube, and feeding ≥ 6 L of colostrum in the first 24 h of life
Nutritional Management							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Terré et al. (2006)	Spain	11.5-92 d	Holstein	40	Experimental, randomly allocated	Unlimited access to starter	Group-raising calves following a growth-promoting feeding program does not increase starter consumption
Quigley et al. (2006)	United States	3-8 d	Holstein	120	Experimental, randomly allocated	Amount of MR feeding	An increase in MR feeding resulted in higher MR intake, less calf starter, greater BW, BW gain, and feed efficiency. It also showed a greater mortality due to diarrhea and required more veterinary assistance. Feed costs and costs/kg of BW gain were also greater

(*Continued*)

Table 1.

Information on Management Strategies Affecting the Well-being in Veal Calves (Domain 1: Nutrition) (Continued)

					Nutritional Management		
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Roth et al. (2009)	Switzerland	0-12 w	Holstein, Brown Swiss	47	Experimental, randomly allocated	End of milk provision age or concentrate-dependent weaning	Weaning average age of 76 d for concentrate-dependent method (vs. 84 d) led to a faster physiological development
Hulbert et al. (2011)	United States	0-3 w	Holstein	44	Experimental, randomly allocated	Feeding frequency	One feeding of MR during the first month evidenced transient neutrophilia, suppression of neutrophils functional capacities, without affecting TNF-α secretion. Change of feeding frequency after 21 d decreased TNF-α secretion
Bernal-Rigoli et al. (2012)	United States	2-66 d	Holstein	50	Experimental, randomly allocated	Feeding method (bottle-fed or bucket-fed)	Group-housed calves were 2.5 kg heavier than individual calves 3 w before weaning, consuming more than individually housed calves due to higher DMI during pre-weaning
Maccari et al. (2014)	Germany	0-3 w	Holstein	48	Experimental, randomly allocated	Feeding frequency	*Ad libitum* feeding of acidified milk in the first 3 w of life of individually housed calves was practical and led to daily weight gains of >1 kg/d. Results suggest that early life nutrition impacts long-term performance
Murray et al. (2018)	Ireland	19 d	Holstein, Jersey	72	Descriptive cohort	Nutritional plane	Haptoglobin could predict exposure to BHV. BRSV appears to be more important at the group-level than at the animal-level. The substantial connections between pre-weaning antibody levels to specific pathogens and its variations over the peri-weaning period may suggest a cohort of genetically connected 'better responders' among the animals exposed
Sharon et al. (2020)	United States	1-68 d	Holstein	36	Experimental randomly allocated	MR feeding method	The risk of ruminal bloat and diarrhea was higher in HPN-fed calves, but there was no difference in antibiotic treatment or mortality. HPN calves performed better in the pre-weaning period, including final BW, ADG, and feed efficiency, but weaning was more stressful for HPN calves. HPN-fed high-risk calves had increased pre-weaning ADG, but also increased incidence of diarrhea
Wilson et al. (2020)	Canada	1-9 d	Not specified	640	Descriptive longitudinal prospective	Amount of milk feeding	Negative health outcomes were more probable for calves at the farm of origin if they had navel illness, low BW, and a downbeat attitude

Type of production system was *indoor* for all the studies. ADG: average daily gain; BHV: bovine herpesvirus; BRSV: bovine respiratory syncytial virus; BW: body weight; CMS: colostrum management score; d: day; DMI: dry matter intake; FTPI: failed transfer of passive immunity; g: gram; h: hour; HPN: high plane nutrition; Ig: immunoglobulin; kg: kilogram; L: liter; MR: milk replacer; TNF-α: tumor necrosis factor alpha; w: week.

The nutritional domain 1 encompasses the provision of water and feed for the animals. Inadequate nutritional selection occurs when animals which typically have access to a variety of feeds, are consistently fed the same, albeit nutritious, feed over extended periods. Despite its substantial impact on the efficiency and profitability of dairy operations, calf nutrition has traditionally been overlooked in dairy management. Nevertheless, it remains of paramount importance for calf health and welfare. The correlation between nutrition and welfare is significant because proper nutrition plays a crucial role in maintaining the overall well-being of animals. Calf nutrition serves as a critical management tool for ensuring calf survival.

Practices related to colostrum management have been previously discussed to ensure the transfer of passive immunity in dairy calves. In general terms, these recommendations focus on the quality, quantity, and timing of colostrum administration, which aligns with the findings of our SR. In a recent scoping review, authors outlined three key steps for optimizing immunity transfer in dairy calves: milking techniques, colostrum treatment and storage, and administration procedures. In addition, they suggested weighing newborn calves and adjusting the feeding volume accordingly to ensure that each calf receives the appropriate amount of colostrum (Robbers et al., 2021).

Table 2.

Information on management strategies affecting the well-being in veal calves (Domain 2: Environment)

Housing Conditions							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Veissier et al. (1997)	France	2 w	Holstein, Montbeliard	64	Experimental, not randomly allocated	Social and physical enrichment	Calves raised in isolation showed more startling expression; calves deprived of objects spent more time nibbling on food blisters, licking their lips, and rolling their tongues. Social exposure and object delivery had no impact on neurological measures and growth; contact with neighbors causes a slight but not significant increase in illness; social deprivation of calves increases behavioral responses
Calvo-Lorenzo et al. (2016)	United States	4 d - 12 w	Holstein	60	Experimental, randomly allocated	Space available	A greater space allowance at 3 w before weaning and throughout postweaning period were associated with positive ADG and BW, a decreased peripheral eosinophil concentration, and lying time after 46 d, but increased eye discharge. Space allowance did not influence fecal consistency at 3 w of age
Kovacs et al. (2019)	Hungary	30-35 d	Holstein	16	Experimental	Artificial shade provision	Cortisol levels in saliva increased from 51 to 342% during the morning of heat stress day (8:00 – 12:00) in all treatments (shaded and non-shaded calves). High cortisol concentrations were observed in non-shaded calves
Renaud et al. (2018b)	Canada	Not specified	Dairy	4825	Descriptive cohort prospective	Housing (location)	Dehydration, housing location within the farm, umbilical abnormalities, arriving in the summer, and the presence of a sunken flank were identified as factors associated with early-life mortality. Late mortality was associated with housing location within the farm, being derived from auction facilities, and an abnormal navel
Hulbert et al. (2019)	United States	4 d - 12 w	Holstein	54	Experimental, randomly allocated	Housing (space)	MOD calves did not show a haptoglobin response to each step of weaning, and appeared to have immune resilience; calves raised in MOD hutches could be weaned and placed into pens at an earlier age (closer to 6 w of age) to avoid restricting their ability to turn around freely
Transportation Conditions							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Fisher et al. (2014)*	Australia	5-9 d	Holstein	59	Experimental, not randomly allocated	Transportation with different consignment held and times	Calves expended 22-32% of the time laying down during transportation and did not show a rebound effect in lying behavior after arrival vs. control calves. The 6-12 h transport method —including indirect transit through the holding facility, did not significantly alter biomarkers vs. not transported animals
Wilson et al. (2020)	Canada	1-9 d	Dairy	640	Descriptive longitudinal prospective	Long distance transportation	Negative health outcomes were more probable for calves at the farm of origin if they had navel illness, low BW, and a downbeat attitude

(*Continued*)

Table 2.

Information on management strategies affecting the well-being in veal calves (Domain 2: Environment) (Continued)

Transportation Conditions							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Marcato et al. (2022a)	The Netherlands	14-28 d	Holstein, Blue Belgian	512	Experimental, not randomly allocated	Transportation (age)	Calves moved after 28 d experienced fewer mortality and non-antibiotic treatments than calves transported after 14 d of age. On the farm, Other than Belgian Blue×Holstein Friesian received more individualized antibiotic and other medical treatments than calves transported at 14 d
Marcato et al. (2022b)	The Netherlands	14-28 d	Holstein, Blue Belgian	Not specified	Experimental, not randomly allocated	Transportation (age)	A negative relationship was found between N-IgG titer and being individually treated with antibiotics or other medicines. 28-d transported calves showed advanced development of adaptive immunity vs. 14-d transported ones

*Type of production system *not specified* (for the other studies was *indoor*). ADG: average daily gain; BW: body weight; d: day; w: week; MOD: 1.85m^2/calf; N-IgG: natural immunoglobulin G.

Within the dairy industry, the timely provision of adequate colostrum to calves is widely recognized as the foremost factor in preventing calf morbidity and mortality (Godden et al., 2019). The optimal timeframe for colostrum feeding ranges from 1 hour (Lora et al., 2018) to 6 hours (Fischer et al., 2018) after birth, beyond which the likelihood of achieving the desired response (IgG absorption) begins to decrease. This response is crucial for the calf's viability, as well as the method of delivery. It is important to acknowledge that the findings may sometimes be complex and nuanced, considering specific aspects of each report. In this sense, while Chigerwe et al. (2008) recommend feeding 150–200 g of colostral IgG via an esophageal tube within 2 hours after birth for correct passive transfer, Renaud et al. (2020) reported that tube feeding resulted in an elevated Failure of Passive Transfer Immunity (FPIT). Conversely, Renaud et al. (2018a) found a correlation between tube feeding and a heightened likelihood of dairy farms being categorized with higher mortality rates in veal operations. The authors suggested that this association might be linked to the quantity of colostrum administered and the timing of feeding. Prior research has indicated that administering 3 L of colostrum within a three-hour window is suitable for enhancing the transfer of colostrum from the forestomach to the abomasum, compensating for the lack of stimulation of the esophageal groove (Lateur-Rowet & Breukink, 1983)

In the realm of nutritional management, the feeding amount and method of milk replacer appear to be relatively understudied topics. Our findings suggest that regardless of the quantity and method used, this practice yields both positive and negative outcomes (Quigley et al., 2006; Sharon et al., 2020; Wilson et al., 2020). On the positive side, it leads to reduced consumption of calf starter, increased body weight, and enhanced growth rates. However, there are also negative aspects, such as increased mortality due to diarrhea and higher veterinary costs. The effect of milk replacer on feed efficiency remains an area requiring further investigation and clarification.

The environmental Domain 2) focuses on the affective impact effects of the physical and atmospheric factors to which the animals are directly exposed. Because the animals are unable to escape from situations in which the effects are unpleasant, they are categorized as unavoidable physical conditions. For instance, in inadequate indoor dwellings, these variables might include characteristics related to space and housing location (Calvo-Lorenzo et al., 2016; Hulbert et al., 2019; Renaud et al., 2018b), floor substrate, atmosphere (Kovács et al., 2019), odor, temperature, noise, and light some of which may also lack natural variation. Each of these conditions is unpleasant and may cause distinct types of discomfort (Renaud et al., 2018a). Many of these issues could also affect animals housed outdoors, especially those kept in close quarters or at high densities, and those without access to shade when it is hot or windy, or shelter when it is cold.

While often underexplored, the aspect of social interaction is undeniably fundamental in the realm of animal welfare, as supported by the five domains model proposed by Mellor et al. (2020). Veissier et al. (1997) observed that calves raised in isolation displayed heightened expressions of startle responses. Furthermore, calves deprived of social interaction or objects tended to engage in detrimental behaviors and exhibited intensified behavioral responses.

Long-distance transport of male calves can significantly impact their welfare. Factors such as transport duration, environmental conditions, handling practices, and overall management during transport play crucial roles in determining these impacts. Prolonged transport, lasting at least 12 hours, can induce stress and fatigue in male calves (Fisher et al., 2014). Extended confinement in transport vehicles may cause physical discomfort, exhaustion, and heightened stress levels. Stress can compromise the calves' immune systems, rendering them more susceptible to diseases (Marcato et al., 2020). Dehydration and nutritional imbalances are common concerns during long journeys, as limited access to water and feed can adversely affect the calves' health and well-being. Inadequate nutrition may result in weight loss and compromised immune function. Extreme weather conditions, such as high temperatures or cold weather, can exacerbate stress levels, disrupt thermoregulation, and further compromise welfare. To mitigate the adverse effects of long transportation on male calves, various measures can be implemented, including gentle

Table 3.

Information on Management Strategies Affecting the Well-being in Veal Calves (Domain 3: Health)

Productive Procedures							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Thuer et al. (2007)	Switzerland	21-28 d	Simmental, Simmental × Holstein	70	Experimental, randomly allocated	Castration	Acute pain was reduced by using local anesthesia in both techniques, being the Burdizzo method considerable preferable to the rubber ring castration
Becker et al. (2012)	Switzerland	4-6 w	Simmental, Simmental × Holstein	63	Experimental, randomly allocated	Castration	Calves castrated with three rubber rings showed inflammation and severe swelling. Less pain during palpation and rapid healing time were observed in castration using one rubber ring, removed on d 9
Dockweiler et al. (2013)	United States	≤ 8-w-≥ 6-m	Holstein	76	Experimental, randomly allocated	Castration	The castration is recommended at an early age and with the use of analgesic compounds at the time of surgery, especially in older calves
Daros et al. (2014)	Canada	0-42 d	Holstein	13	Experimental, not randomly allocated	Dehorning	Separation from the dam induced a pessimistic response bias in a judgment task. The same response was observed in induced dehorning. Therefore, cognitive bias proposes an emotional response to pain and social loss
Martin et al. (2021)	United States	10-14 w	Holstein	50	Experimental, randomly allocated	Dehorning	Pain management during dehorning using bupivacaine liposome suspension was effective as a multimodal approach of local anesthesia (lidocaine) and non-steroidal anti-inflammatory drugs (meloxicam)
Nogues et al. (2021)	Canada	28 d	Holstein	21	Experimental, pseudo-randomly allocated	Castration	More inflammation and a higher skin temperature were observed after rubber ring castration. Those castrated with rubber bands gained less BW during the study period, mainly due to a lower DMI
Health Issues							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Wilson et al. (2020)	Canada	1-9 d	Not specified (dairy)	640	Descriptive longitudinal prospective	Presence of navel disease and depressed attitude	Negative health outcomes were more probable for calves at the farm of origin if they had navel illness, low BW, and a downbeat attitude

Type of production system was *indoor* for all the studies. BW: body weight; DMI: dry matter intake; Ig: immunoglobulin; d: day; w: week.

loading and unloading practices to minimize stress and the risk of injury. Given that transportation regulations and guidelines differ across regions, adherence to appropriate animal welfare standards is crucial to minimize negative impacts on male calf welfare during long transports.

According to Mellor et al. (2020), domain 3 focuses on how disease, injury, and varying levels of physical qualification affect animal´s welfare, causing pain. According to the results presented here, the main approaches of interest when evaluating the generation and degree of pain in male calves are mainly related to practices such as castration (Becker et al., 2012; Dockweiler et al., 2013; Nogues et al., 2021; Thüer et al., 2007) and dehorning (Daros et al., 2014; Martin et al., 2022), aiming to define the best age (e.g., early age, 4–6 weeks) and methods (e.g., rubber ring technique and Burdizzo clamp), as well as medications (e.g., local anesthesia and analgesia) to reduce the possibility of pain or discomfort as the main decision point. Based on our findings, it appears that the most effective protocol for castration involves the use of local anesthesia, preferably administered using the Burdizzo method at the earliest possible stage in the calf's

Table 4.

Information on Management Strategies Affecting the Well-being in Veal Calves (Domain 4: Behavioral Interactions)

Social Interaction							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Veissier et al. (2001)	France	3-7 d	Montbeliard	32	Experimental, semi-randomly allocated	Reaggregation	Calves interacted with their new partner and increased their overall mobility in response to the initial mixing, but they vanished by the ninth. Regrouped calves were more active at the end of the day and less active at night when all relocations were finished, and cortisol responses to exogenous ACTH were higher
Bernal-Rigoli et al. (2012)	United States	2-66 d	Holstein	50	Experimental, randomly allocated	Individual or group housing	Group-housed calves were 2.5 kg heavier than individual calves 3 w before weaning, consuming more than individually housed calves due to higher DMI during pre-weaning
Costa et al. (2014)	Canada	0-70 d	Holstein	36	Experimental, not randomly allocated	Individual rearing or group rearing	The novel feed consumption was higher in socially than individually housed calves. Social rearing decreased the latency to eat the novel feed
Costa et al. (2015)	Canada	0-70 d	Holstein	40	Experimental, randomly allocated	Early pair housing or late pair housing	Early-paired calves consumed more calf starter and showed higher ADG than separately raised or late-paired calves
Contact with the dam							
Reference	**Country**	**Age**	**Breed**	**Population Size**	**Study Design**	**Management Strategy of Analysis**	**Conclusions**
Grondahl et al. (2007)*	Norway	0-13 w	Not specified	56	Experimental, not randomly allocated	Cow-calf contact	Rearing with cow-calf contact included a DWG higher than the mean (1.4 kg vs. 0.95 kg). No drugs (*i.e.,* probiotics, hormones, vaccines) were not used. Antibiotics were only used during disease.
Daros et al. (2014)	Canada	0-42 d	Holstein	13	Experimental, not randomly allocated	Cow-calf contact	Separation from the dam induced a pessimistic response bias in a judgment task. The same response was observed in induced dehorning. Therefore, cognitive bias proposes an emotional response to pain and social loss
Mac et al. (2023)*	Australia	0-109 d	Holstein-Friesian	6 (cow-calf pairs)	Experimental, not randomly allocated	Cow-calf contact	With an average carcass dressing percentage of 59%, the ADG was 1.4 0.73 kg/d. During separation for milking, cow vocalizations and attempts to return to their calf reduced over time; calf closeness and suckling frequency were highest in the first 2 w and declined with experiment duration
Webb et al. (2022)	The Netherlands	0-4 w	Holstein, Blue Belgian	57	Experimental, not randomly allocated	Cow-calf contact	The IgG, IgA, and IgM levels did not differ between treatments, but a high level of leukocytes was found in dam-reared calves reflecting exposure to pathogens. Suckling calves showed more fear towards humans at w 5-7

*Type of production system *outdoor/grazing* (for the other studies was *indoor*). ACTH: adrenocorticotropic hormone; ADG: average daily gain; kg: kilogram; DMI: dry matter intake; DWG: daily weight gain; d: day; w: week; Ig: immunoglobulin.

life. In addition, the concurrent use of analgesic compounds during the surgical procedure further enhances the effectiveness of the protocol. In this context and given that improving calf welfare has the added benefit of maintaining the social acceptance of the cattle industry and enhancing producer mental health and job satisfaction, it is challenging and crucial to develop practical, safe, affordable, and cost-effective pain-management strategies that can be readily adopted by farmers and used repeatedly on the farm. However, the main obstacles are economic and cultural perceptions of male calves within the sector, issues that still need to be addressed in the systems of interest globally, supported by research approaches that delve into better established well-being indicators, as to date and according to our results, these are still limited.

As animals interact with their environment, other nonhuman creatures, and humans, there is behavioral evidence suggesting that the manifestation of agency can be both hindered and enhanced. Agency occurs when animals engage in voluntary behaviors based on a cognitive evaluation of the circumstances or situations surrounding them (Mellor et al., 2020). The expression of agency-focused responses and behaviors to situational elements is captured by domain 4, known as behavioral interactions (Mellor et al., 2020). In relation to this domain, the expression of natural behaviors, such as social interactions, is closely linked to calf welfare, despite the common practice in many commercial dairy farms of separating the calf from the dam within 24 hours of calving (Meagher et al., 2019) and subsequently rearing the calves individually (De Paula Vieira et al., 2010).

Raising calves without social contact—including the interaction with the dam, can have adverse effects on their natural behaviors and welfare (Hötzel et al., 2017). Social housing provides calves with the opportunity to engage in social behaviors and may offer them more usable space (Costa et al., 2015). In this SR, two relevant articles (Costa et al., 2014; 2015) found that socially housed calves exhibited reduced food neophobia and increased solid feed intake and weight gain compared to individually housed calves. These findings align with the study by De Paula Vieira et al. (2010), which demonstrated that calves housed in pairs early in life started consuming solid feed earlier than those housed individually. Overall, it can be concluded that social contact positively influences calves' feeding behavior. Conversely, the absence or restriction of certain agency-related behaviors, such as social contact, may lead to negative affective states (Mellor et al., 2020). Individually housed calves may experience such negative effects due to the restriction of social behaviors. Therefore, providing calves with the opportunity for social housing can replace potential negative effects with positive ones, thereby enhancing calf welfare.

The mental state of the animal, which is primarily produced by the brain's processing of sensory inputs evoked by external stimuli, is evaluated via domain 5 according to Mellor (2017), who claims that various causes produce negative or positive impacts in each domain. Whether the resulting impacts are adverse or advantageous depends on how successfully the animals used their behavioral strategies to accomplish their desired aims.

None of the practices evaluated and reported in the relevant articles were directly related to this last domain. However, as expressed by Mellor (2017), all the domains have an impact on it. Just to mention an example, one of the relevant articles states that calves with a failed transfer of passive immunity were more likely to develop a depressed attitude after transport (Wilson et al. 2020). A depressed attitude could be related to a negative affective state, thus affecting domain 5. As the authors note, the calf's "attitude" may be predictive of poor health outcomes. Domain 5 allows for a final assessment of the overall welfare of the animal, understood in terms of what it is likely to subjectively experience (Mellor, 2017).

Several studies included in this SR were conducted within an indoor calf housing system aimed at improving performance while maintaining acceptable welfare standards. It is imperative that such housing adequately meets the basic needs of the animals to safeguard their well-being. On the other hand, the grazing conditions have been scarcely explored because most of the studies have been conducted in seasonal countries under indoor production systems. Grazing conditions are important to the authors since in most tropical countries with a growing dairy industry (i.e., Colombia and Brazil) dairy calves are reared in outdoor rearing systems.

Our SR offers several advantages. We adhered to a formal procedure that was based on a well-defined research topic and had been previously reported and approved by SRs with expertise in the field of health. To identify potential studies, we conducted a comprehensive literature search across a significant number of databases and sources, including general-purpose databases, search engines, journals, and conference proceedings, allowing us to capture information dating back to 1949. We did not impose geographic or chronological restrictions, thereby minimizing the risk of bias. Furthermore, the information extracted from the initial searches was meticulously defined. One author created a matrix of findings, which was then reviewed by a second author to ensure consistency, given the variation in quality and technique among the relevant studies.

However, our SR may have some limitations. Many documents may be challenging to locate and obtain, and we did not fully consider the gray literature. To mitigate this, we employed snowballing techniques. In addition, a significant number of studies identified during the search process did not explicitly differentiate outcomes by sex and were therefore not included in our analysis. This may have resulted in the exclusion of several studies that reported management practices with both positive and negative effects on male calf welfare.

Conclusion and Recommendations

Management strategies with negative effects on calf welfare include inadequate feeding of high-quality colostrum within a few hours of birth, lack of a colostrum management program, dehorning/castration without local anesthesia or analgesia, and long-distance transportation of calves younger than 14 days old. Conversely, opportunities to improve male calf welfare include practices such as ad libitum feeding, rapid calf starter introduction, socially grouped housing, adequate hutch space, and pain management during routine procedures.

While the basic needs of animals are well-known from literature and ancestral knowledge, there is still much to explore regarding positive conditions in nutrition, environment, health, and behavioral interactions and mental state. Practices such as providing correct quantities of water, balanced and varied food, ensuring enough

space for movement on well-drained substrates, providing fresh air, effective shelter, proper lighting, noise control, and allowing animals moments of rest, feeding, and recreation can all contribute to improved welfare and need to be further analyzed.

In general, it cannot be definitively concluded that one practice is less detrimental to the welfare of male dairy calves. Under the five domains model approach, the integration of different stimuli, mainly processed by the brain's sensory inputs, determines whether associated effects are negative or positive. Therefore, if a practice has a more or less positive effect on welfare, that would be incorrect, as the integrated result of all negative and positive mental experiences accumulated in domain 5 represents the animal's current welfare state.

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