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# Improving animal welfare on dairy farms with special emphasis on calf management

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# Summary


### Improving animal welfare on dairy farms with special emphasis on calf management

Livestock welfare, including dairy cows and calves, has gained importance for society, politics, and agriculture over the last decades. Providing kept animals with a high level of animal welfare requires the implementation of scientific recommendations and husbandry standards affecting dairy cow and calf welfare, on top of the minimum standards set by law. In this regard, it is essential to better understand the decision-making process of animal keepers, as they ultimately have the most significant impact on the welfare of their animals. Accordingly, this thesis aimed at investigating the implementation of management recommendations for calf husbandry on dairy farms, at deriving recommendations for management aspects that have been neglected so far, at analyzing the relationship between the attitude of animal keepers and animal welfare management, and at evaluating the applicability of animal welfare self-assessments in calf husbandry. Management recommendations and animal welfare indicators were derived from the literature and evaluated in interviews with livestock farmers and calf assessments (n > 800 calves). The evaluation of the farm management showed that many management recommendations have not been implemented yet. Furthermore, the stockpersons' view on animal welfare was identified as a significant factor influencing the implementation of recommendations. In this thesis, it was found that wound lesions caused by legally required ear tagging are a prevalent animal welfare problem. Corresponding recommendations to minimize the risk of such lesions were derived. The implementation of animal welfare self-assessments could increase awareness of the performing livestock keepers to the described welfare aspects. Animal welfare indicators suitable for inclusion in self-assessments were evaluated. Furthermore, related influencing factors such as calf age or climatic conditions were analyzed to increase the reliability of welfare indicators. Evaluated behavioral assessments for self-assessment in calves were feasible but dependent on the time of day of the assessment and the person observing. In conclusion, the findings obtained in this thesis constitute further progress towards a reliable and practicable animal welfare assessment and thus towards an improvement in the welfare of dairy calves.

# Zusammenfassung


## Verbesserung des Tierwohls auf milchviehhaltenden Betrieben unter besonderer Berücksichtigung des Kälbermanagements

Das Wohlergehen von Nutztieren und somit auch das von Milchkühen und Kälbern hat in den letzten Jahrzehnten zunehmend an Bedeutung in Gesellschaft, Politik und Landwirtschaft gewonnen. Um Nutztieren ein hohes Maß an Tierwohl zu ermöglichen, ist es nötig, dass zusätzlich zu den gesetzlich festgelegten Tierwohl-Mindeststandards auch darüber hinaus wissenschaftliche Empfehlungen und Haltungsstandards umgesetzt werden. Diesbezüglich ist es essenziell den Prozess der Entscheidungsfindung von Tierhalter*innen besser zu verstehen, da ihr Handeln schlussendlich ausschlaggebend für das Wohlergehen ihrer Tiere ist. Dementsprechend war das Ziel dieser Arbeit die Umsetzung von Managementempfehlungen in der Milchviehkälberhaltung zu untersuchen, Empfehlungen für bisher weniger beachtete Managementaspekte zu entwickeln, den Zusammenhang zwischen der Einstellung der Tierhalter*innen und dem Tierwohlmanagement zu analysieren sowie die Umsetzbarkeit von Tierwohl-Eigenkontrollen in der Kälberhaltung zu beurteilen. Dazu wurden Managementempfehlungen und Tierwohlindikatoren aus der Literatur abgeleitet und im Rahmen von Interviews mit Tierhalter*innen und durch Bonitierungen von Kälbern (n > 800) evaluiert. Die Evaluierung des Betriebsmanagements zeigte, dass viele Managementempfehlungen noch nicht umgesetzt wurden. Die Einstellung der befragten Tierhalter*innen zur Thematik Tierwohl wurde als ein ausschlaggebender Faktor für die Umsetzung von Empfehlungen identifiziert. Ferner konnte in dieser Arbeit gezeigt werden, dass Wundläsionen durch das gesetzlich vorgeschriebene Einziehen der Ohrmarken ein prävalentes Tierwohlproblem darstellen. Entsprechende Empfehlungen zur Minimierung des Risikos dieser Läsionen wurden abgeleitet. Die Durchführung von Tierwohl-Eigenkontrollen könnte Tierhalter*innen für die beschriebenen Tierwohl-Aspekte weiter sensibilisieren. Die Erfassung potenzieller Tierwohlindikatoren wurde erprobt und Zusammenhänge zu beeinflussenden Variablen wie dem Kälberalter oder Witterungsbedingungen herausgearbeitet, um so die Reliabilität der Indikatoren zu steigern. Verhaltensbeurteilungen für Kälber zur Nutzung in Eigenkontrollen waren praktikabel, jedoch von der Tageszeit der Erhebung und der beobachtenden Person abhängig. Die im Rahmen dieser Arbeit gewonnen Erkenntnisse stellen weitere Schritte zu einer reliablen, praktikablen und umfassenden Bewertung des Tierwohls und somit auch zu einer Verbesserung des Wohlergehens von Milchviehkälbern dar.

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# List of abbreviations

| | |
|---|---|
| BMEL | Bundesministerium für Ernährung und Landwirtschaft |
| BMJV | Bundesministerium der Justiz und für Verbraucherschutz |
| BW | body weight |
| C | continuous question |
| CD | Council Directive |
| CI | confidence interval |
| CR | Council Regulation |
| DFC | Dairy Farmers of Canada |
| EC | European Commission |
| EFSA | European Food Safety Authority |
| EU | European Union |
| FARM | Farmers Assuring Responsible Management |
| FAWC | Farm Animal Welfare Council |
| Ig | immunoglobulins |
| IGF | insulin-like growth factor |
| ISO | International Organization for Standardization |
| KTBL | Kuratorium für Technik und Bauwesen in der Landwirtschaft |
| NA | not assessable |
| NFACC | National Farm Animal Care Council |
| NOT | Novel Object Test |
| NS | numerical scale |
| O | open question |
| Obs | observer |
| OiE | World Organization for Animal Health |
| OR | odds ratio |
| p.p. | postpartum |

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|---|---|
| QBA | Qualitative Assessment |
| QM-Milch | Qualitätsmanagement-Milch e.V. |
| QN | qualitative nominal question |
| QO | qualitative ordinal question |
| Reg. | regulation |
| RSH | Reaction to Stationary Human Test |
| SCC | somatic cell count |
| SD | standard deviation |
| spp. | species pluralis |
| sQBA | simplified Qualitative Behaviour Assessment |
| TÄHAV | Verordnung über tierärztliche Hausapotheken |
| TierSchG | Tierschutzgesetz |
| TierSchNutztV | Tierschutz-Nutztierhaltungsverordnung |
| TierSchTrV | Tierschutztransportverordnung |
| UCLA | University of California |
| US | United States of America |
| USDA | United States Department of Agriculture |
| VA | visual assessment |
| ViehVerkV | Viehverkehrsverordnung |
| WQ | Welfare Quality® Project |

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# 1. Introduction

Parts of this chapter are published in Hayer, J. J., B. Petersen, and J. Steinhoff-Wagner. 2018. Extrinsische Qualitätskriterien in der Wertschöpfungskette Milch. Pages 125–163 in Qualitätsmerkmal Tierwohl. C. Gothe, and B. Petersen, ed. tredition, Bonn, Germany.

## 1.1. General introduction

While the animal's welfare is a function of its states in coping with environmental conditions (Broom, 1986), the future viability of farmers could be described as their ability to cope with societal and market demands. Especially in the last two decades, animal welfare has gained more importance in society, science, and the dairy industry (Keyserlingk and Weary, 2017). In 2006 and 2016, the European Commission (EC) commissioned a survey to determine citizens' opinions on the welfare of animals kept in the European Union (EU) (EC, 2007, 2016). A comparison of both surveys shows that the percentage of respondents in Germany who consider animal welfare very important increased from 40% to 61% between 2006 and 2016. This increase was accompanied by a constant demand for more information about the conditions under which animals are kept (56% and 53% of respondents stated to want more information in 2006 and 2016, respectively). Furthermore, most respondents (83%) stated in 2016 that ensuring the welfare of animals kept in Germany should be given a higher priority. These results are reflected in the consumer survey conducted by Kantar EMNID (2017), in which 83% of the participants stated that farmers should treat their animals responsibly. Correspondingly, the German political advisory board, major dairy quality assurance schemes, and international researchers recognize animal welfare as an integral part of sustainable and future dairy farms (Flint et al., 2016; Keyserlingk and Weary, 2017; Barkema et al., 2015; Wissenschaftlicher Beirat Agrarpolitik beim BMEL, 2015).

Simultaneously, with increased animal welfare awareness, the international and national dairy sector experienced profound changes that may directly or indirectly affect animal welfare. Dairy farms in Germany and worldwide are in an ongoing structural change, resulting in fewer but larger farms, which was exacerbated by the abolishment of the milk quota in 2015 and subsequent fluctuations of milk prices (Barkema et al., 2015). Furthermore, and in addition to animal welfare, other sustainability goals such as preventing the development and spread of antimicrobial-resistant microorganisms or environmental protection have gained importance (Barkema et al., 2015; Herzog et al., 2018). However, it is unclear how these sustainability goals interact and how they influenced farm management and animal welfare (Herzog et al., 2018). Although most studies focused on changes in adult dairy cow management rather than dairy calf management, international studies indicate that dairy calf management is poor. Therefore, approaches to improve the animal welfare of dairy calves are urgently needed.

Before presenting the scientific approaches to measure and improve calf welfare elaborated in this thesis, it is essential to create a shared understanding of animal welfare, calf management, and animal welfare assessment.

## 1.2. Animal welfare in livestock production

### 1.2.1. Definition and concepts of animal welfare

Although the term "animal welfare" is widely used in the livestock industry, in academia, and society at large, the concept itself is quite new and, inherently, evolving as society's views are changing and animal welfare science evolves (Broom, 2011; Green and Mellor, 2011). Basically, according to Broom (2011), the term "animal welfare" describes "a potentially measurable quality of a living animal at a particular time." The World Organization for Animal Health (OiE) defines animal welfare as "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (OiE, 2019). However, the concept has multiple dimensions (e.g., scientific, cultural, religious, or economical), is value-laden, and changes according to social development in societies, making it a challenging term to define and measure (Fraser, 2008; Veasey, 2017). Hence, the aim of this chapter is not to discuss all animal welfare concepts used or all dimensions of animal welfare but to elaborate on the concepts and understanding to be used in this thesis.

*Scientific animal welfare concepts*

The beginning of social awareness about animal welfare is commonly associated with the book "Animal Machines" by Ruth Harrison in 1964 (Harrison, 1964; Broom, 2011; Keyserlingk and Weary, 2017). The description and criticism of common housing practices for poultry and veal calves and the following public reaction motivated the British government to commission a report on the husbandry conditions of farm animals (Brambell, 1965). This report and its recommendations served as the basis for the first animal welfare concept (Broom, 2011; Keyserlingk and Weary, 2017).

The concept of "Five Freedoms," developed by the Farm Animal Welfare Council (FAWC) in 1992, was intended to provide a framework for analyzing animal welfare based on: (1) freedom from thirst and hunger; (2) freedom from discomfort; (3) freedom from pain, injury, and disease; (4) freedom to express normal behavior; and (5) freedom from fear and distress. In addition, the "Five Freedoms" were assigned steps and compromises to ensure and improve animal welfare, referred to as the "Five Provisions" (Figure 1.1) (FAWC, 1993; Webster, 2016). After almost 30 years since its introduction, this concept is still applied in its original form in various fields and still forms the basis for animal welfare regulations of the EC (Veissier et al., 2008; Mellor, 2016b; Webster, 2016; European Union, 2020). Recently, however, the concept has been criticized by researchers. One criticism is that it focuses exclusively on the freedom from negative states and harm, ignoring the experience and reinforcement of positive states (Mellor, 2016b; Lawrence et al., 2018; Lawrence et al., 2019; Rault et al., 2020). Moreover, the concept could be misunderstood as aiming for a complete absence of negative experiences, which would be impossible and undesirable, as Mellor (2016a) reviewed. Nevertheless, the concept has the advantage of being easily accessible – even to non-scientists – while highlighting the most critical aspects of animal welfare in a timeless form (Webster, 2016).

Shortly after the introduction of the concept of "Five Freedoms," Mellor and Reid (1994) introduced their concept of "Five Domains," which was based on the "Five Freedoms" concept but was modified and initially aimed at assessing and minimizing consequences of animal experiments or use. In its original version, the concept proposed that any welfare compromise would occur in one or more of five domains: (1) thirst/hunger/malnutrition; (2) environmental challenge; (3) disease/injury/functional impairment; (4) behavioral/interactive restriction; (5) anxiety/fear/pain/distress. A system for evaluating the overall welfare compromises has also been integrated (Mellor and Reid, 1994). In contrast to the "Five Freedoms" concept, the "Five Domains" concept has been regularly updated since its initial introduction to incorporate livestock, wildlife, and companion animals but also positive emotions and states (Green and Mellor, 2011; Mellor, 2012; Mellor, 2016b). As such, the "Five Domains" concept provides a framework that scientists can use to analyze specific topics, identify new areas of research, or develop outcome-based animal welfare protocols (Webster, 2016; Mellor, 2017). The "Five Domains" concept has recently been used in studies to evaluate animal sensors regarding animal welfare (Fogarty et al., 2019), to evaluate animal welfare indicators in sheep (Hernandez et al., 2020), to create an animal welfare risk assessment in zoos (Sherwen et al., 2018), and to rate husbandry practices in horses (McGreevy et al., 2018). However, since a single researcher or a panel of researchers categorize and evaluate animal welfare relevance, the concept lack objectivity (McGreevy et al., 2018; Fogarty et al., 2019).

A third well-known, additional, and complementary concept, created by Fraser (2003), defines three areas of concerns on how animals should be kept or their welfare analyzed: (1) biological function (e.g., health, growth, and reproduction); (2) affective state (minimizing pain and promoting contentment); (3) natural living. A key aspect of this concept is that a holistic consideration of all three concerns helps identify conflicts between the three concerns in evaluating husbandry measures (Fraser, 2003). Particularly in North America, for example, it is still common to separate calves from their dams and rear them in single housings to reduce the risk of infection and facilitate management (biological function). Nevertheless, recent studies highlight the importance of social interaction of calves and the benefits of group housing and therefore advocate housing calves in groups (natural living) despite the potential risks (Costa et al., 2019). However, these three areas of concern can also overlap for certain measures (Figure 1.1) (Fraser, 2003; Keyserlingk et al., 2009). For example, an unweaned dairy calf unable to drink more than 6 L of milk per day in restrictive feeding programs (natural living) will most likely feel hunger or thirst or both (affective state) and may have hindered growth and will be more susceptible to infections (poor biological function). Another feature of the concept is its focus on the fact that animal welfare is value-laden and that stakeholders may have different views/concerns regarding animal welfare-related measures – which may coincide or contradict each other (Fraser, 2003). An example of different stakeholder values and their importance can be found in comparing farmers' and consumers' values on animal welfare. On the one hand, farmers have been shown to believe that healthy and productive animals are evidence of high animal welfare (Benard and Cock Buning, 2013; Albernaz-Gonçalves et al., 2021), related to biological function and affective state. On the other hand, consumers value natural behavior and naturalness as the essential aspect of animal welfare (Benard and Cock Buning, 2013; Yeates, 2018). Therefore, informing consumers about current husbandry practices as a means to improve social acceptance – as proposed by farmers in the study of Benard and Cock Buning (2013) – will most likely be unsuccessful due to the differences in values (Boogaard et al., 2006; Fraser, 2008). The German scientific Advisory Board for Agricultural Policy also stated in 2015 that informing consumers alone is unlikely to improve social acceptance of current livestock production (Wissenschaftlicher Beirat Agrarpolitik beim BMEL, 2015). Thus, it is necessary to address all three animal welfare concerns in evaluating animal welfare measures, husbandry systems, or social acceptability (Fraser, 2003, 2008; Keyserlingk et al., 2009).

A common aspect of all previously described concepts, which is also mentioned in Broom's (2011) definition of animal welfare, is that animal welfare refers most often to a status at a specific point in time. One concept that differs regarding this aspect is the "Quality of life" concept, which was transferred from the social sciences and human medicine to animal welfare science (Scott et al., 2007) and was formulated by the FAWC (2009). This concept proposes that an animal's quality of life can be assessed and categorized into "a life not worth living," "a life worth living," and "a good life" (Figure 1.1) (FAWC, 2009). An animal's quality of life assessment aims to evaluate welfare throughout the entire animal's life, including the manner of death (FAWC, 2009). Accordingly, any animal living a life not worth living, in which the negative experiences outweigh positive experiences, would be better off dead or have its quality of life rapidly improved (FAWC, 2009; Green and Mellor, 2011). A life worth living is defined in the original proposal as full compliance with animal welfare regulations (FAWC, 2009), although studies indicate that only complying with animal welfare regulations does not satisfy all animal needs (Boissy et al., 2007; Duval et al., 2020; Turner, 2020a). The highest level (a good life) includes best practices, as described in welfare codes, and good stockmanship (FAWC, 2009). Since its introduction, the concept has been reviewed extensively (Green and Mellor, 2011; Yeates, 2011; Yeates, 2012; Webster, 2016; Yeates, 2017) and partially adapted (Figure 1.1) (Green and Mellor, 2011). Researchers have embraced the idea of evaluating animal welfare throughout their lives and comparing the affective states of animals. However, the concept has been criticized for being highly subjective (e.g., different values of observers), speculative (prediction of future welfare), and not applicable to groups (Green and Mellor, 2011; Yeates, 2017). Nonetheless, it could be a valuable tool to avoid negative states (a life not worth living) (Yeates, 2012) or to facilitate decision-making in euthanasia cases (Webster, 2016).

As Webster (2016) mentioned, the applicability of a particular animal welfare concept and understanding fundamentally depends on by whom and for what purpose it is used. For example, a researcher developing an assessment protocol to evaluate animal welfare needs a much more sophisticated and complex concept than a retailer that integrates minimum animal welfare standards. Furthermore, concepts can differ regarding their applicability, as certain concepts are designed to be applied in practice, while others approach animal welfare from a philosophical, theoretical angle (Figure 1.1).

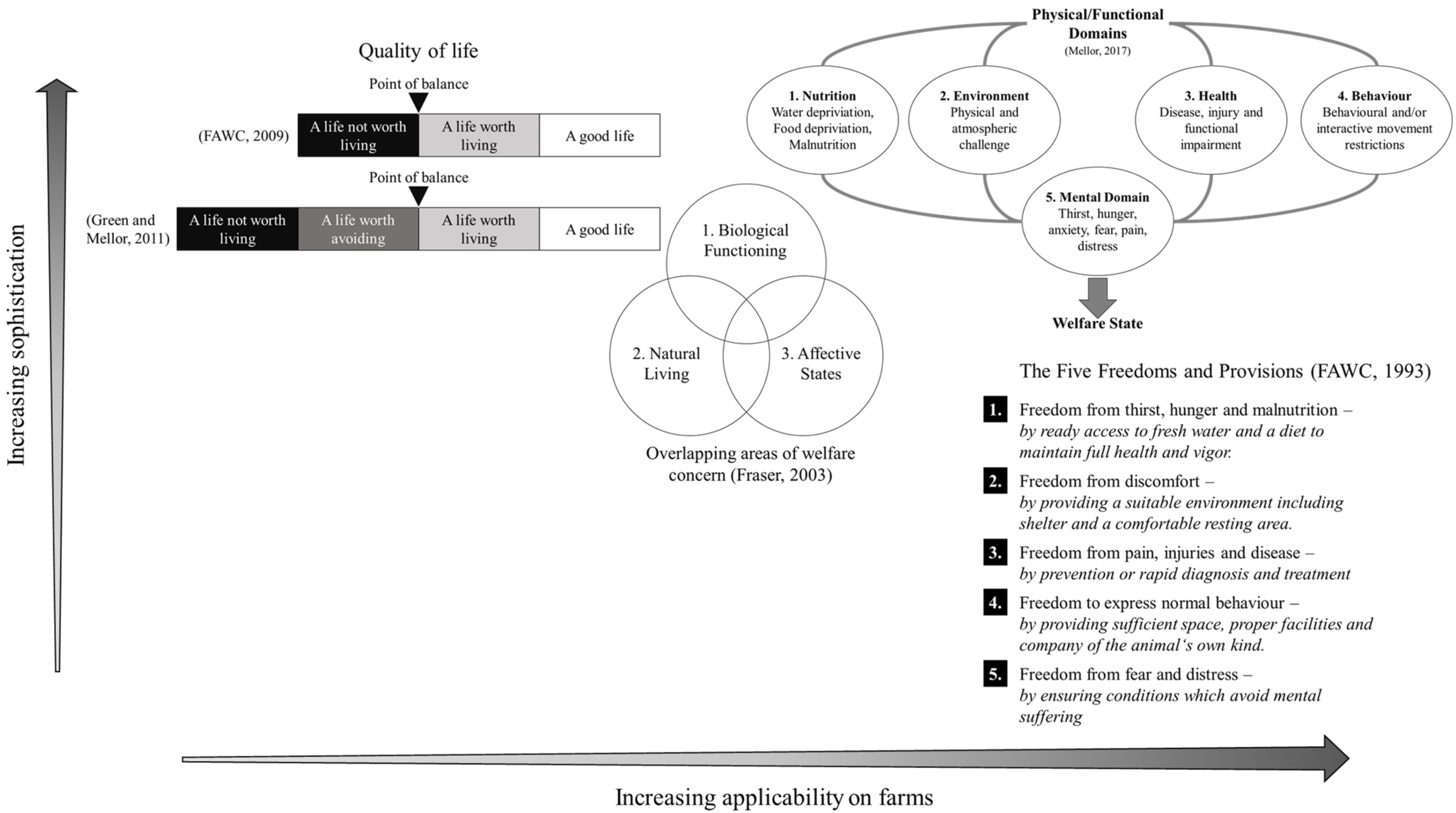


**Figure 1.1.** Selected animal welfare concepts arranged according to their sophistication and applicability on farms based on discussions about the concepts (FAWC, 1993; Fraser, 2003; FAWC, 2009; Green and Mellor, 2011; Mellor, 2016b, 2017; Webster, 2016).

In the following chapters, the elaborated concepts of animal welfare are used according to their purpose and applicability: The "Five Freedoms" are used to understand animal welfare regulations and general welfare principles, the "Five Domains" are applied to categorize animal welfare indicators and their use, the three areas of concern developed by Fraser (2003) are helpful to understand the perspective of different stakeholders, while the "Quality of Life" concept is needed to understand welfare aspects that transcend the boundaries of a single point in time.

*Developments in animal welfare thinking*

Based on the described concepts, several movements are currently being discussed in animal welfare science. As a reaction to the focus on avoiding negative states in animals (e.g., the concept of "Five Freedoms"), the idea of promoting and focusing on positive animal welfare has emerged (Lawrence et al., 2018; Lawrence et al., 2019). Furthermore, attention has been drawn to the aspect of natural living and whether keeping animals under natural conditions, where they can behave naturally, should be recognized as optimal from an animal welfare perspective (Veasey, 2017; Yeates, 2018; Learmonth, 2019; Beaver et al., 2020). From these two discussions emerged the idea of providing animals the opportunity to perform highly motivated behaviors and choose preferred conditions and elements of the housing environment to achieve peak animal welfare, rather than focusing on natural conditions and behaviors (Veasey, 2017; Learmonth, 2019; Špinka, 2019). John Webster, one of the founders of the "Five Freedoms," endorsed this conclusion when he stated that he would paraphrase the fifth freedom (freedom to express normal behavior) today as "Freedom of choice" (Webster, 2016). An example of this approach is keeping dairy cows on pasture, which is considered as most important by consumers, farmers, and welfare assessments (Welfare Quality®, 2009; Cardoso et al., 2019). Legrand et al. (2009) conducted a behavioral-choice study to determine whether cows prefer indoor housing or pasture and how environmental conditions might affect cow's preference. They found that cows preferred to stay indoors during the day, especially when the temperature-humidity index was high, mainly consuming feed. In contrast, cows preferred pasture during the night, where more lying behavior was observed (Legrand et al., 2009). Further choice and behavioral studies are needed to identify peak animal welfare conditions.

However, animal welfare is not independent of surrounding influencing aspects such as the environment or interacting humans. Accordingly, to improve livestock animal welfare sustainably, other aspects such as monetary factors, work safety for farmers, or environmental considerations must be evaluated simultaneously (Balzani and Hanlon, 2020). A multidisciplinary approach to simultaneously improve animal, human and environmental welfare offers the concept of “One Welfare,” which has emerged out of the “One Health” concept and recognizes the connection between animal welfare, human welfare, and environmental well-being (Pinillos et al., 2016).

## 1.3. Dairy calf welfare

After defining and elaborating on animal welfare and its concepts, three practical questions arise concerning animal welfare and dairy calf rearing: “What is the current animal welfare status in dairy calf rearing in Germany?”, “Which factors affect animal welfare of dairy calves?” and “How could it be improved?”.

### 1.3.1. Animal welfare in dairy calf rearing

In order to enable dairy calves to have a “good life,” it is necessary for farmers to fully comply with animal welfare recommendations, exceeding the minimal animal welfare regulations (FAWC, 2009; Mellor, 2016b). Based on aspects affecting dairy calves’ welfare, many management recommendations have been derived that should be implemented on the farms (DFC-NFACC, 2009; Costa et al., 2019). On the one hand, established management recommendations are available for aspects such as colostrum and milk feeding management. On the other hand, clear recommendations for social contact and hygiene in calf management are currently only partially available (Figure 1.2). The following section briefly discusses the availability of management recommendations using these examples and elucidates the distinction between painful procedures and other management aspects.

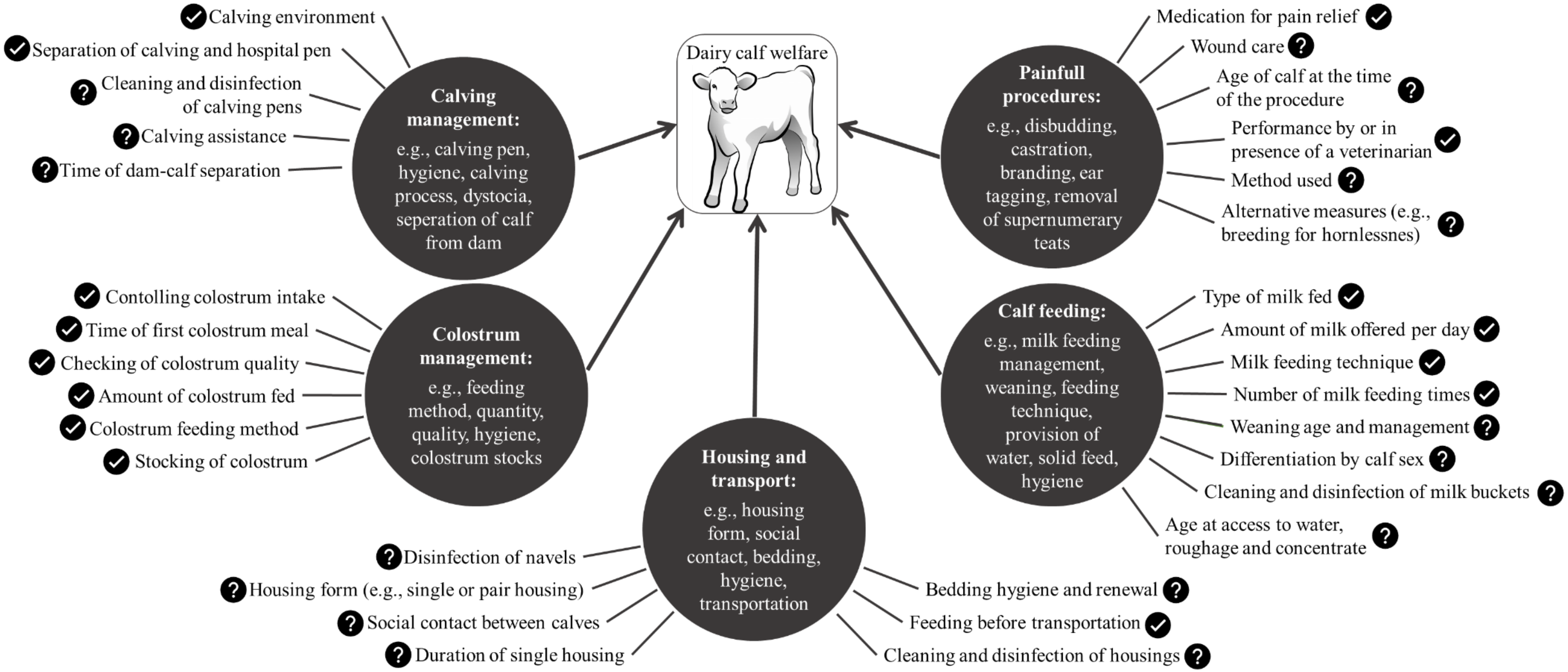


**Figure 1.1.** Examples of management aspects of dairy calf management that influence animal welfare, derived from previous literature research and rated according to the availability of recommendations (Detailed description and sources are displayed in Supplemental Table S7.1). Animal welfare aspects with established management recommendations are marked with a "✓," while aspects with only partly available recommendations are marked with a "?".

Colostrum management provides several examples of well-researched management recommendations. Successful provision of sufficient amounts of colostrum can be seen as the single most crucial factor influencing postnatal calf health and mortality (Godden, 2008), because in utero transmission of immunoglobulins (Ig) from dam to calf is physiologically unlikely, thus making the calf immune system almost entirely dependent on the absorption of Ig-containing colostrum (Arthur, 1996; Godden et al., 2019; Barry et al., 2019b). For a successful passive immune transfer, it is recommended to feed calves 10–12% of their body weight (BW) (3–4 L in case of Holstein calves) of high-quality colostrum (> 50 g IgG/L) within the first 2 h postpartum (p.p.) (Godden et al., 2019). Although these recommendations are well known in science and practice (DFC-NFACC, 2009; Godden et al., 2019), international studies indicate that– despite their importance for calf health and welfare – these measures are not implemented regularly on dairy farms (Klein-Jöbstl et al., 2015a; Urie et al., 2018; Winder et al., 2018; Barry et al., 2019a).

Another example of established management recommendations is the volume of milk fed to calves. Feeding calves less than 6 L milk per day (< 15 % of their average BW before weaning) has been associated with signs of hunger (Thomas et al., 2001; Rosenberger et al., 2017), increased cross-sucking (Jensen, 2003), and reduced growth during the milk feeding period (Rosenberger et al., 2017). Based on these findings, it has been recommended to increase milk allowance to at least 8 L milk per day (Costa et al., 2019).

Other aspects of animal welfare have only recently gained more attention, and no optimal management recommendation has been derived yet. For example, early separation of calf and dam has been recommended to prevent disease transmission from dam to calf and ensure early colostrum intake (Godden., 2008; Mee, 2008). In contrast, recent publications concluded that prolonged cow-calf contact promotes normal social behavior, reduces calf and maternal stress, and does not necessarily increase the risk of disease transmission (Beaver et al., 2019; Meagher et al., 2019; Placzek et al., 2021). Furthermore, hygiene has been described as an essential factor for the health of dairy calves, but clear recommendations to ensure and control hygiene have been missing (Mee, 2008). Nevertheless, Donat et al. (2016) found that cleaning and disinfecting calving pens after every calving was the most effective measure to prevent the transmission of *Mycobacterium avium* spp. *paratuberculosis* from dam to calf. Moreover, milk buckets have recently been identified as a potential source of disease transmission, and first recommendations to ensure hygiene have been proposed (Heinemann et al., 2021). Recommendations for these aspects are only partly available, and further research is needed to identify best practices.

Routine but painful management procedures stand out from other animal welfare aspects because they are performed intentionally and inevitably cause distress in calves. Studies have been conducted to identify management procedures to minimize unnecessary suffering of calves during castration and disbudding, recommending the administration of sedatives, analgesics, and local anesthesia for the procedures (Stafford and Mellor, 2011; Costa et al., 2019). For other procedures, such as ear tagging or removal of supernumerary teats, few studies exist on the effects on calf welfare, on-farm management, and measures to reduce the pain and distress caused. The number of German farms that routinely remove supernumerary teats is unknown (86% of Canadian farms; Vasseur et al. (2010)), whereas each calf must be ear-tagged on both ears within the first seven days p.p. (BMJV, 2007). Identification of animals by measures such as ear tagging enables their traceability between farms, countries, and along the value chain, thus providing a link between animal health and food safety (Schroeder and Tonsor, 2012). However, recent studies on ear tagging showed that it is associated with pain-related behavior such as head shaking, tail wagging, or foot stamping (Leslie et al., 2010; Lomax et al., 2017; Turner et al., 2020b) and increases in heart rate (Stewart et al., 2013) and cortisol levels (Numberger et al., 2016). Despite the direct impact on animal welfare, risk factors for animal welfare impairments caused by ear tagging, management recommendations for calves are currently missing.

### 1.3.2. Dairy calf welfare in Germany

According to the structural assessment in October 2019, 59,900 dairy farms housing approximately 4 million dairy cows are located in Germany (BMEL, 2021). In recent decades, the dairy production sector has been undergoing constant structural change, with a decreasing number of farms (101,202 dairy farms in 2007) and an increasing number of cows per farm (40 cows per farm in 2007, 67 cows per farm in 2019) (BMEL, 2017, 2021). Even though precise numbers of dairy calves are unknown (only the total number of calves, including beef calves), it can be assumed that the structural change of dairy farms also affects dairy calf husbandry. Animal welfare of dairy calves has recently received more attention from the scientific community as scientists conducted surveys on animal welfare of calves in different countries (Hötzel et al., 2014; Staněk et al., 2014; Klein-Jöbstl et al., 2015b; Urie et al., 2018) and developed animal welfare protocols (Barry et al., 2019b). Translating results of international studies to German calf husbandry is challenging as Germany differs from other countries regarding structure, climatic conditions, or political frameworks. Furthermore, it is important to consider regional differences in dairy cow husbandry in Germany, as regions differ in breeds kept or farm size. Nevertheless, data on the animal welfare status of dairy calves kept in Germany and its regions are currently still missing.

### 1.3.3. Approaches to improve dairy calf welfare

In their review, Christensen et al. (2019) described four main approaches to improve animal welfare on-farm: governmental regulations, consumer choice (labeling), food companies, and producer-driven initiatives. In the following chapters, the effects of governmental regulations and producer initiatives are primarily considered. Since food companies can only indirectly influence animal welfare by influencing consumers choice, both approaches (consumer choice and food companies) will be merged and only briefly discussed.

*Animal welfare regulations*

Animal welfare regulations lay down minimum animal welfare standards to prevent unnecessary pain, suffering, or injury (EU, 1998; Christensen et al., 2019; Nalon and Stevenson, 2019). The focus on providing minimal standards might also be the reason why EU animal welfare regulations are aligned to the “Five Freedoms” (Veissier et al., 2008; Vogeler, 2019; EU, 2020). This focus is also reflected in the German word “Tierschutz” (Animal protection), which is frequently used as a synonym to animal welfare but is defined as “all legislative measures to protect animals from cruelty, abandonment, killing without reasonable cause, etc.” (Duden, 2021). However, this does not necessarily mean that animals kept according to legal requirements enjoy a high level of welfare but rather live a life worth living (FAWC, 2009; Nalon and Stevenson, 2019). One reason is that legal regulations frequently lack specificity, such as “calves must not come into contact with urine or feces more than unavoidable; a dry lying area must be available to them in the barn” (BMJV, 2001). Moreover, detailed regulations for whole species, such as dairy cows, are missing in the EU and Germany (Christensen et al., 2019; Nalon and Stevenson, 2019). Therefore, consumers and researchers advocate revising animal welfare regulations and implementing more restrictive regulations (Nalon and Stevenson, 2019; Pejman et al., 2019; Duval et al., 2020). However, implementing stricter welfare regulations entails costs for farmers to adapt to the new regulations and for the government and society to enforce and monitor compliance (Christensen et al., 2019). In addition, strict regulations can increase the risk of relocation of production to other regions and countries with lower animal welfare regulations, resulting in no real welfare gain or even lower total animal welfare (Christensen et al., 2019). Another aspect of animal welfare regulations is that they are only effective if they are enforced and monitored by official controls (Lundmark

Hedman et al., 2018; Nalon and Stevenson, 2019). In contrast, official animal welfare controls are currently only rarely conducted. For example, in Sweden, only 10% of all farms are yearly controlled, which is even higher than in France, where only 1% are yearly controlled (Lundmark Hedman et al., 2018; Veissier et al., 2021). Control effectiveness is also hampered by the circumstance that the indicators used are often not perceived as valuable by inspectors and farmers (Lundmark Hedman et al., 2018; Veissier et al., 2021).

The welfare of animals kept in Germany is protected by European and national legislation (Table 1.1). At the European level, minimum requirements for animal welfare, in general, are laid down in the Council Directive (CD) 98/58/EC (EU, 1998). This basic framework is extended by detailed regulations on keeping farm animals (including calves but not adult cattle) (EU, 2009) and regulations for specific topics such as transportation (EU, 2005) or identification (EU, 2019). On the federal level, the German Animal Welfare Act provides general principles for the protection of animals and specific regulations for aspects such as painful procedures or animal experiments (BMJV, 1972). More detailed regulations on keeping animals are laid down in the Ordinance on the Protection of Animals and the Keeping of Farm Animals (BMJV, 2001), which transposes European regulations such as CD 98/58/EC or CD 2008/119/EC into German federal law. Likewise, German regulations on the transportation and identifications of animals have been enacted to incorporate European law (BMJV, 2007, 2009). Both European and German animal welfare regulations include basic animal welfare principles aligned to the “Five Freedoms”: Animals must be provided with feed and water according to their needs; animals’ housing environment must not be harmful to the animal; keepers must ensure that animals kept are not caused any unnecessary pain, suffering or injury; and the natural behavior of animals shall not be restrained in a way that causes pain or suffering (BMJV, 1972, 2001; EU, 1998, 2009). However, German regulations exceed European regulations in several specifications, such as the time between the first colostrum meal (4 h vs. 6 h) or the minimum age of calves to be transported (14 d vs. 10 d) (Table 1.1). Nevertheless, important minimum standards for protecting calves are not yet included in animal welfare regulations (e.g., the minimum volume of colostrum provided, the minimum volume of daily milk allowance, specific hygiene measures, pain reduction measures for exeptions from local anesthesia, or social contact between calves). Since 2014, the German Animal Welfare Act includes § 11 Section 8, which states that farmers are required to conduct self-assessments by using suitable animal-based welfare indicators (chapter 1.4). However, the regulation lacks a definition of “suitable animal welfare indicators,” a specification on the frequency of assessments, their documentation, and the control of assessments.

**Table 1.1.** Specific animal welfare regulations regarding the management of dairy calves on EU and German federal level, exceptions (e.g., exceptions for small farms) are not presented.

| Animal welfare area | EU level | German federal level |
|---|---|---|
| General aspects | • Inspections of animals by keepers at least twice a day[1, 3] | • Inspections of animals by keepers at least twice a day[5, 6] |
| | • Sick calves must be treated immediately, and a veterinarian must be contacted if needed[3] | • Sick calves must be treated, separated immediately, and a veterinarian must be contacted if needed[6] |
| | • Record keeping of medical treatments and mortalities on farm[1] | • Record keeping of medical treatments and mortalities on the farm, including the cause of deaths[6] |
| | | • Livestock keepers must conduct and evaluate self-assessments to ensure animal welfare standards using animal-based welfare indicators[5] |
| Colostrum management | • Colostrum must be provided for each calf within 6 h p.p.[3] | • Colostrum must be provided for each calf within 4 h p.p.[6] |
| Housing | • Single housing only until 8 weeks of age; specifications on height and length of individual pens according to the size of the calf[3] | • Single housing only until 8 weeks of age; housing size of at least 120 cm length, 80 cm wide, 80 cm height for calves > 14 d of age, and 160–180 cm length for calves 2–8 weeks of age[6] |
| | • Single housing must be perforated to allow direct visual and tactile contact[3] | • Outer walls of calf housings must be perforated to allow direct visual and tactile contact[6] |
| | | • Walls of calf housing must be sufficiently thermally insulated[6] |
| | • Space specifications for group housing (1.5 $m^2$ for calves < 150 kg; 1.7 $m^2$ for calves 150–220 kg; 1.8 $m^2$ for calves > 220 kg)[3] | • Space specifications for group housing (1.5 $m^2$ for calves < 150 kg; 1.7 $m^2$ for calves 150–220 kg; 1.8 $m^2$ for calves > 220 kg)[6] |
| | • Materials in animal's housing environment must not be harmful to the animal and should be thoroughly cleanable and disinfectable[1, 3] | • Materials in animal's housing environment must not be harmful to the animal and should be thoroughly cleanable and disinfectable[6] |
| | • Air circulation, dust levels, temperature. relative air humidity and gas concentration must be kept below harmful limits[1, 3] | • The temperature of the lying area should not exceed 25°C or go below 5°C (10°C for calves < 10 d); humidity of 60–80%[6] |
| | | • Upper thresholds for gas concentrations (20 $cm^3$ $NH_3/m^3$; 3000 $cm^3$ $CO_2/m^3$; 5 $cm^3$ $H_2S/m^3$)[6] |

| Animal welfare area | EU level | German federal level |
|---|---|---|
| Housing | • Provision of sufficient lighting to meet physiological and ethological needs[1] | • The lighting of at least 80 Lux for at least 10 h per day according to their daily rythm[6] |
| | • Housing must be constructed to allow lying down, rest, stand up, and grooming; permanent tethering is not allowed[3] | • Housing must be constructed to allow lying down, rest, stand up, grooming, and unhindered consumption of feed and water; permanent tethering is not allowed[6] |
| | • Flooring must not be slippery or harmful for calves lying or standing on it[3] | • Flooring must not be slippery, not harmful; specific thresholds for slatted floors (2.5 cm gap width)[6] |
| | • The lying area must be comfortable, clean, and adequately drained; appropriate bedding for all calves < 14 d of age[3] | • Calves must not get in contact with excretion if avoidable, a dry stable with soft and elastic bedding must be provided; the lying area must be designed to meet all requirements of lying and, in particular, to avoid heat dissipation[6] |
| | • Housing, pens, equipment, and utensils used must be properly cleaned and disinfected; Feces, urine, and spoiled food must be removed as often as necessary[3] | • Housing, pens, equipment, and utensils used must be properly cleaned and disinfected; Feces, urine, and spoiled food must be removed as often as necessary[6]<br>• In the case of indoor housing, manure or slurry must be removed from the lying area at required intervals, or new bedding must be added regularly[6] |
| Transport | • Only animals fit for transport shall be transported (e.g., able to move, no open wounds, healed navel)[2]Only calves of at least 10 d of age can be transported[2] | Reference to EU legislation (Reg. (EC) 2/2005)[8] |
| | • Only calves of at least 10 d of age can be transported[2] | • Only calves of at least 14 d of age can be transported[7] |
| Feeding | • Calves shall not be muzzeld[3] | • Calves shall not be muzzled[6] |
| | • Feed must contain sufficient iron to ensure an average blood hemoglobin level of min. 4.5 mmol/L[3] | • Feed must contain sufficient iron to ensure an average blood hemoglobin level of min. 6.0 mmol/L[6] |
| | • Calves must be feed at least twice a day[3] | • Calves must be feed at least twice a day; fulfilling calves need to suckle[6] |
| | • In group-housed calves, each calf must have access at the same time as the other in the group, except ad libitum feeding or automatic feeding system[3] | • In group-housed calves, each calf must have access at the same time as the other in the group, except ad libitum feeding or automatic feeding system[4] |

| Animal welfare area | EU level | German federal level |
|---|---|---|
| Feeding | • Calves > 14 d of age must have access to a sufficient quantity of fresh water; in hot weather and for ill calves, water must always be available[1, 3] | • Calves > 14 d of age must have access to a sufficient quantity of fresh water[5, 6] |
| | • A ratio of fibrous feed must be provided for calves > 14 d[3] | • Ratio of fibrous feed must be provided for calves > 7 d[6] |
| | • Feeding and watering equipment must be designed, placed, and managed to minimize contamination[3] | • Feeding and watering equipment must be designed and placed to allow consumption and to minimize contamination and agonistic behavior[6] |
| Painful procedures | Reference to the regulations of member states[1] | • Painful procedures without anesthesia are forbidden, exceptions: castration of calves (< 4 weeks); disbudding of calves (< 6 weeks); identification by electronic transponders, ear tags or flags[5] |
| | | • In case of exceptions of anesthesia, any means necessary to reduce pain needs to be applied[5] |
| | • Application of ear tags or electronic identifier at both ears on the farm of birth by keepers[4] | • Application of ear tags or electronic identifier at both ears on the farm within 7 d p.p. by keeper7 |

[1](EU, 1998), [2](EU, 2005), [3](EU, 2009), [4](EU, 2019), [5](BMJV, 1972), [6](BMJV, 2001), [7](BMJV, 2007), [8](BMJV, 2009)

*Labels and consumer choice*

Improving animal welfare by consumer choice is based on the idea that consumers pay a price premium for products labeled as animal welfare-friendly that exceed the legal minimums (Christensen et al., 2019). In Germany, several labels have been developed that promote higher standards of animal husbandry and thus have the potential to improve the welfare of the animals kept in these conditions: e.g., "Neuland" (since 1988), European organic standard (since 2012), "Tierschutzlabel" (since 2013), "Initative Tierwohl" (since 2015), or the "Haltungsform" standard (since 2019) (Christensen et al., 2019; Duval et al., 2020; Stiftung Warentest, 2021). However, most of the labels focus on meat production, and only a few, for example, the organic labels and the "Tierschutzlabel," also include dairy products. Moreover, the few labels for dairy farms include only a limited number of requirements for dairy calves, such as painless disbudding and mortality thresholds in the Tierschutzlabel (Deutscher Tierschutzbund e.V., 2021). Although governments currently prefer market-based instruments such as labeling over regulations, improvements in animal welfare are highly dependent on consumers' willingness to pay (Veissier et al., 2008; Frey and Pirscher, 2018). International and national studies showed that consumers rank animal welfare as highly important and state that they would be willing to pay higher prices for higher animal welfare standards, regardless of the species (Zühlsdorf et al., 2016; Clark et al., 2017; Frey and Pirscher, 2018; Pejman et al., 2019). However, consumers' purchasing behavior often deviates from their claims made, leading to the so-called "citizen-consumer attitude-behaviour gap" and low margins of animal welfare premium products (Akaichi and Revoredo-Giha, 2016; Wissenschaftlicher Beirat Agrarpolitik beim BMEL, 2015; Vigors, 2018; Enneking et al., 2019). Furthermore, labeling of products alone does not seem to be sufficient, as many people are unaware of animal welfare labels (85.9% reported not knowing any animal welfare label) (Zühlsdorf et al., 2016). Providing additional information on the product has been shown to increase the likelihood of purchasing these products (Cornish et al., 2020).

Retailers can indirectly enhance consumer choice by advertising animal welfare labeled foods, reducing the selection of animal products offered to mainly products with higher animal welfare standards, or placing animal welfare products more visibly (Christensen et al., 2019). For example, Lidl, Germany's second-largest food retailer, aims to exclude meat products of the lowest "Haltungsform" level (conventional farming), milk from tethered cows, and to enforce the application of anesthesia for disbudding of calves in the medium term (Lidl, 2020).

*Farmer-driven initiatives*

Farmers' decision-making arguably has the most significant impact on farm animal welfare, as farmers decide to comply with legal regulations or implement superior animal welfare recommendations (Hansson and Lagerkvist, 2016; Kauppinen et al., 2010). In an attempt to understand farmers' decision-making regarding animal welfare, researchers have developed a conceptual framework that assumes that this process is influenced by "use values" and "non-use values" (McInerney, 2004; Lagerkvist et al., 2011; Hansson and Lagerkvist, 2016; Hansson et al., 2018; Balzani and Hanlon, 2020). Use values are values associated with the use of livestock in the production process for economic purposes (e.g., ensuring animal health to reduce treatment costs or workload) (McInerney, 2004; Lagerkvist et al., 2011; Hansson et al., 2018). On the other hand, none-use values describe values that producers derive from the well-being of animals that are independent of any use (e.g., ethical reasons) (McInerney, 2004; Lagerkvist et al., 2011; Hansson et al., 2018). In a survey among Swedish dairy farmers, Hansson and Lagerkvist (2016) reported that decision-making was influenced by both use and non-use values, with farmers ranking non-use values particularly high. "To feel happy knowing that my dairy cows are well-kept." was the primary attribute according to the farmers surveyed. Besides the values described, several other factors influence the implementation of animal welfare recommendations, such as knowledge, trust, personality, time, labor condition, or feasibility in general (Balzani and Hanlon, 2020). Following Ajzen's (1991) Theory of Planned Behavior, Ritter et al. (2017) elaborated factors influencing the adoption of on-farm management strategies for disease prevention and control. Arguably, this framework can also be applied to understand farmer decision-making regarding animal welfare recommendations, as disease prevention is a part of animal welfare and shares similarities such as hidden costs or its preventive nature (Figure 1.3) (Ritter et al., 2017; Balzani and Hanlon, 2020).

Knowledge of farmers' understanding of animal welfare and the associated factors are fundamental for improving the welfare of animals on-farm (Kauppinen et al., 2010; Hansson and Lagerkvist, 2016; Hansson et al., 2018; Balzani and Hanlon, 2020). Therefore, further research in this arena is necessary to identify factors and challenges associated with animal welfare management strategies (Balzani and Hanlon, 2020).

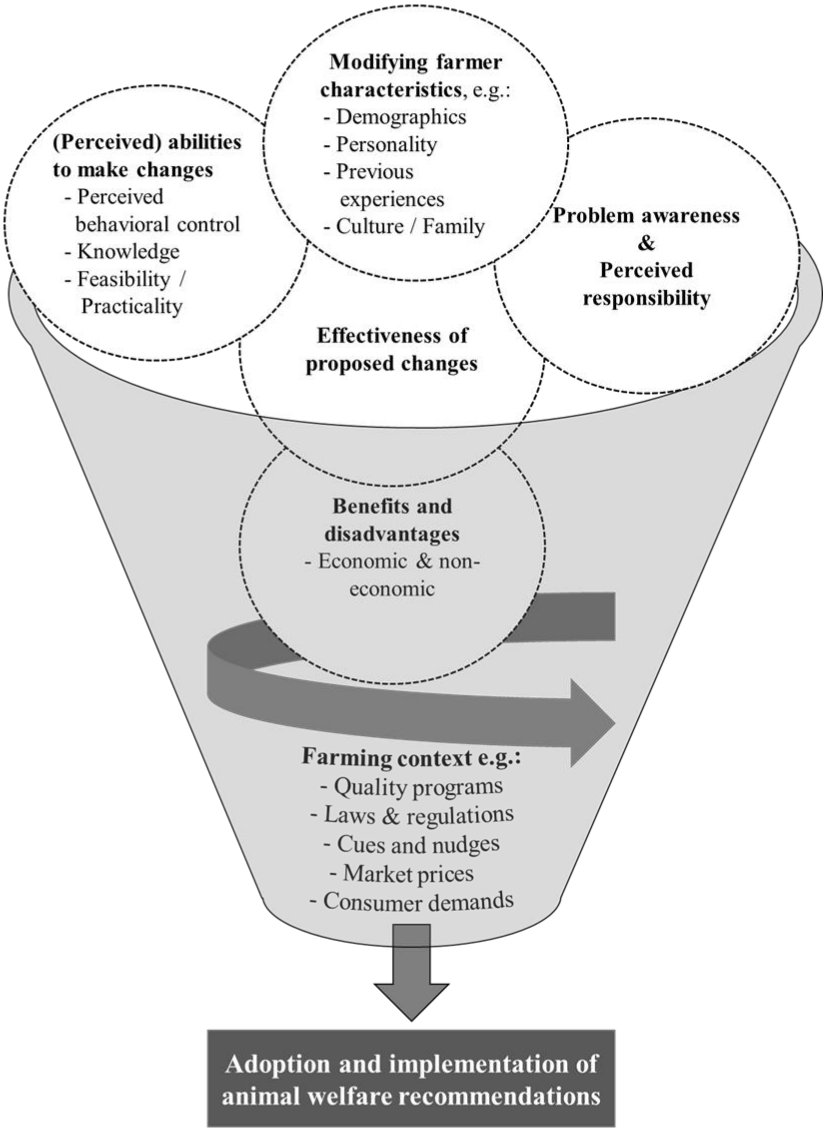


**Figure 1.2.** Socio-psychological factors leading to the adoption of management procedures to incorporate recommendations for improved animal welfare (modified from Ritter et al. (2017)).

## 1.4. The assessment of calf welfare on dairy farms

Like the elaborated difficulties and complexities in defining animal welfare, assessing animal welfare has been proven equally challenging (Hockenhull and Whay, 2014). Animal welfare – as described previously – is a multi-dimensional, complex construct that combines both subjective and objectives aspects and therefore requires multiple and specific indicators to be assessed (Scott et al., 2003; Scott et al., 2007). In general, the primary function of an animal welfare indicator or measurement is to assign a numerical value to the attribute of interest or to classify an observation (Scott et al., 2003).

### 1.4.1. Classification of animal welfare indicators

Researchers and stakeholders in the livestock industry have proposed a broad range of animal welfare indicators, and new indicators are proposed exponentially. These indicators may overlap to some degree and may be classified differently: For example, indicators can be divided into input- or output-based indicators or into negative and positive animal welfare indicators (Lagerkvist et al., 2011; Turner, 2020a). In this thesis, animal welfare indicators will be categorized into resource-based indicators, management-based indicators, and animal-based indicators following previous publications, assessment protocols, and public agencies (Welfare Quality®, 2009; Lagerkvist et al., 2011; EFSA, 2012; March et al., 2017):

- Resource-based indicators

  These indicators include the animal's living environment and husbandry system parameters and focus mainly on technical aspects such as flooring, bedding material, offered feed, climatic conditions, or space requirements (Lagerkvist et al., 2011; March et al., 2017). They are frequently and relatively easy to observe and assess. However, resource-based indicators are often criticized for assessing the prerequisite for animal welfare rather than animal welfare itself (Lagerkvist et al., 2011).
- Management-based indicators

  Management-based indicators describe and evaluate on-farm management practices and workflows, such as painful procedures, cleaning and disinfection measures, or feeding routines (March et al., 2017). Much like resource-based indicators, the advantage of management-based indicators is the simplicity and objectivity of assessment. At the same time, the main disadvantage is the measurement of necessary conditions rather than good welfare directly (Lagerkvist et al., 2011).
- Animal-based indicators

  In contrast to the other two types of indicators, animal-based indicators focus on the animal itself, including assessment of locomotion characteristics, animal health conditions, body condition scorings, or cleanliness assessments. This category also includes assessments and interpretations of animal behavior (Lagerkvist et al., 2011; March et al., 2017). Animal-based indicators focus directly on the welfare of individual animals, enable immediate identification of impairments, and shift the focus to the individual. However, the assessment of this category is usually more time-consuming, challenging, and prone to errors (de Passillé and Rushen, 2005; Lagerkvist et al., 2011; EFSA, 2012).

Another essential difference between management-, resource-, and animal-based indicators is that the former two are almost exclusively based on a single measurement per farm or group. In contrast, animal-based indicators may also consist of assessments of multiple individual animals. The assessment of welfare indicators at the individual level enables the user to identify changes over time, differences between groups, or the necessity of management adaptions in case of severe animal welfare impairments (Winckler, 2019). Therefore, animal-based indicators are valuable for direct decision-making. In the past, the focus of assessment protocols, legislations, and private guidelines has been on resource- and management-based indicators due to their easy assessment and interpretation (EFSA, 2012). However, the focus of current assessment protocols has shifted to animal-based indicators (Welfare Quality®, 2009; EFSA, 2012; Brinkmann et al., 2016; Barry et al., 2019b). Nevertheless, for third-party audits to check compliance with legal requirements or with animal welfare label standards, which currently only include specific management and housing facility specifications, an assessment of specifically defined indicators seems sufficient (Lundmark Hedman et al., 2018). Farmers who want to continuously improve their on-farm management or the welfare status of their individual animals, or both, require a comprehensive assessment that includes all categories because assessments focusing only on one category of indicators have certain constraints. For example, resource- and management-focused assessments, as described, do not measure animal welfare directly. In contrast, animal-focused assessments do not allow for risk factor analysis or identify the reason behind the results. However, information about both the input and output variables is necessary to enable a successful improvement process (Barry et al., 2019a). Another constraint is that for certain important animal welfare aspects, no applicable animal-based indicator has been developed (e.g., disbudding in calves or early provision of water to calves), requiring the use of resource- or management-based indicators. For example, the early provision of free drinking water, which has been shown to promote calf growth and to modulate gut microbiota composition (Wickramasinghe et al., 2019; Wickramasinghe et al., 2020), is currently only evaluable by resource- and management-based indicators. Nevertheless, possible indicators for dehydration such as skin return time or capillary refill time have been shown to be effective in identifying dehydration in calves deprived of food and water for 24 h (Kells et al., 2020). However, whether these indicators can also be used to measure the benefits of free drinking water for calves that regularly receive milk remains to be evaluated. In conclusion, a combination of indicators of all three categories (resource-, management- and animal-based indicators) might therefore be the most promising approach to assess on-farm and individual animal welfare while simultaneously identifying the adjustments to improve welfare.

### 1.4.2. Quality criteria for animal welfare indicators

Science will most likely never be able to prove that an animal has good or poor welfare, but it can gather evidence from which to draw inferences about animal welfare (Mason and Mendl, 1993). Any indicator used to gain evidence on animal welfare should be valid, reliable, and feasible (Scott et al., 2003; Czycholl et al., 2015).

The validity of an animal welfare indicator describes the extent to which the indicator measures animal welfare or the extent to which it measures what it is intended to measure (Czycholl et al., 2015; Scott et al., 2003). In humans, self-reports have been widely accepted as the primary method to assess wellbeing and happiness validly (Ludwigs et al., 2019). However, animals can currently not be questioned directly about their wellbeing, and there is no other “gold standard” to which animal welfare indicators can be compared (Scott et al., 2003). Species-specific validation studies (e.g., controlled choice studies) or expert validations (e.g., expert panels) are, therefore, currently used to validate animal welfare indicators before their use (Scott et al., 2003; Ison et al., 2016). Regarding animal welfare assessments, especially behavioral animal welfare tests such as the Qualitative Behavior Assessment have been criticized for their lack of validity (de Passillé and Rushen, 2005; Meagher et al., 2016; Winckler, 2019).

Reliability describes the repeatability of an animal welfare indicator or assessment, i.e., repeating the assessment under the same general conditions would produce the same result. (de Passillé and Rushen, 2005). This description includes several components and is no less difficult to evaluate than validity (Mason and Mendl, 1993; de Passillé and Rushen, 2005; Kirchner et al., 2014; Czycholl et al., 2016). Three different reliability criteria can be distinguished:

1. Inter-observer reliability

   is the level of agreement between different observers assessing the same animal or object at the same time under the same conditions;

2. Intra-observer reliability or test-retest reliability

   describes the agreement of repeated assessments of the same object by the same observer at the same time under the same conditions;

3. Consistency over time

   means that the outcome of an animal welfare indicator or assessment represents a long-term situation and is not sensitive to short-term changes or internal states of an animal if housing and management conditions have not changed.

All three reliability criteria are more or less influenced by external or internal factors, referred to as influencing factors in the following. Influencing factors are variables such as assessment conditions (e.g., climatic conditions), differences in husbandry systems (e.g., grazing systems), or characteristics of animals (e.g., species, age, or sex) that influence the outcome of animal welfare indicators or assessments. Therefore, it has been suggested to control them in assessments or consider them when interpreting the results (Mason and Mendl, 1993). Accordingly, for assessing one or more indicators, it is helpful to identify these factors to define a framework for the assessment (e.g., only animals of a certain age or limitation to one season), thus increasing reliability and comparability between farms or repeated assessments. Furthermore, indicators should be useful for evaluating on-farm management and the decision-making of farmers (Scott et al., 2007). Indicators that are strongly influenced by short-term influences could arouse mistrust among farmers and thus hamper their acceptance or lead to wrong management decisions.

The reliability of single animal welfare indicators or animal welfare assessment protocols has been evaluated over the past decade (de Passillé and Rushen, 2005; Czycholl et al., 2016; Czycholl et al., 2019; Friedrich et al., 2019; Pfeifer et al., 2019). While resource- and management-based indicators and animal health indicators have been proven to be predominantly reliable, behavioral indicators seem to lack reliability (de Passillé and Rushen, 2005; Czycholl et al., 2016; Meagher et al., 2016; Czycholl et al., 2019). However, most studies focused only on inter-observer reliability, intra-observer reliability, or both, rather than on consistency over time or influencing factors. Nevertheless, single studies on consistency over time indicated that most data collections were only partly consistent over the medium- or long term. Identified or discussed reasons were seasonal effects, management changes, or short-term fluctuations and effects (Kirchner et al., 2014; Can et al., 2017; Vieira et al., 2018; Czycholl et al., 2021). Although assessing, evaluating, and adjusting to influencing factors could increase consistency over time, only a few studies considered these effects (Vieira et al., 2018). In an attempt to reduce the effect of influencing factors, scientists designed specific protocols for specific breeds or husbandry systems (Barry et al., 2019b; Kaurivi et al., 2020) or limited the assessment to only one sex or animals of a certain age (Barry et al., 2019b).

In the end, animal welfare indicators will only be used to evaluate animals or farms in practice if they are feasible. Feasibility refers to the costs of assessing an animal welfare indicator or protocol (e.g., time, labor, monetary resources, or material required), which should be appropriate to the outcome (Czycholl et al., 2015).

### 1.4.3. Existing animal welfare protocols in dairy farms

Both at the international and national levels, systems are needed that enable a feasible and reliable assessment of animal welfare on farms and a determination of risk factors. Welfare assessments can be used on-farm in several scenarios such as audits, self-assessments, or research scenarios (Botreau et al., 2009). In an animal welfare audit, farms are evaluated by assessing animal welfare indicators and comparing the results with reference values such as legal specifications or standards of animal welfare labels (Botreau et al., 2009; Karapetrovic and Willborn, 2001). In contrast, self-assessments focus on continuous improvement by using indicators to identify strengths, weaknesses, risks, and opportunities for improvement, rather than simply monitoring compliance with standards (Karapetrovic and Willborn, 2001). Implementing and controlling minimum standards, such as legal requirements, is fundamental, but animal welfare can be improved further through a continuous improvement approach, as described in ISO 9001 (Grandin, 2021). The pursuit of continuous improvement also represents the core principle of Total Quality Management, which is the leading concept in modern quality management (Pfeifer, 2002). Total Quality Management focuses on quality management and aims at long-run success through consumer satisfaction (Theuvsen, 2010). Animal welfare is rated as highly important by consumers and has recently gained more importance as a quality criterion in livestock production (Zühlsdorf et al., 2016; Gothe and Petersen, 2018). Therefore, striving for continuous improvement by using animal welfare self-assessments may be considered an integral part of modern quality management in livestock production.

Additionally, the assessment of suitable animal welfare indicators can raise the awareness of stockmen for animal welfare and thus increase the individual perceived responsibility for the welfare of animals kept (Zapf et al., 2017). In Germany, three existing animal welfare protocols for dairy farms are of particular relevance: the Animal Welfare Guideline of the German Association for Technology and Structures in Agriculture (KTBL) (Brinkmann et al., 2016), the Sustainability Module of the QM-Milch e.V. developed by the Thünen Institute (Flint et al., 2016), and the Welfare Quality Protocol developed in the "Welfare Quality Project®" (Welfare Quality®, 2009).

Initiated by the revision of the German Animal Welfare Act and the new obligation of farmers to assess animal welfare on-farm by using animal-based indicators (BMJV, 1972), the KTBL developed animal welfare assessment protocols for on-farm assessment by farmers for most livestock species (dairy cows, fattening cattle, pig, poultry, laying hens, fattening poultry). For animal welfare assessment of calves, a protocol containing eight indicators was published in

2016 (Brinkmann et al., 2016). Preference was given to indicators that are already routinely evaluated on-farm (e.g., treatment incidence of diarrhea), easy to assess by farmers (e.g., cleanliness of animals by a two score-system), and animal-based (Brinkmann et al., 2016; Zapf et al., 2017). Most likely due to this focus, aspects of animal welfare that are hardly assessable by animal-based indicators are left out, such as feeding management or the management of painful procedures. In addition, animal behavioral assessments such as avoidance tests were included in the protocol for dairy cows but not in the protocol for calves (Brinkmann et al., 2016). However, animal behavior is an essential element of animal welfare assessments and should be included in welfare assessments (Boissy et al., 2007). Moreover, several tests have been designed to evaluate calves' behavior (e.g., Qualitative Behavioral Test, Reaction to a Stationary Human test, or the Novel Object Test) (de Passillé and Rushen, 2005; Boissy et al., 2007). Applications of the protocol for pigs have been published, but not for calves (Pfeifer et al., 2019).

Following a different approach, a joint project of the well-established quality assurance QM-Milch e.V. and the Thünen-Institute developed a sustainability module that integrates economic, ecology, sociology, and animal welfare (Flint et al., 2016). This module was not intended to become a component of the QM-Milch audit. Instead, it was designed to assess the status quo of animal welfare on dairy farms and achieve a common understanding within the value chain (Flint et al., 2016). It includes 26 indicators (8 affecting calves directly) that are mainly resource- and management-based. Animal-based indicators are primary disease incidences, which are routinely assessed or estimated by the farmers without direct observation and assessments of individual animals on the farm. After a 3-year pilot study, 27 dairy processors already decided to incorporate this assessment into their quality program (Lindena et al., 2021).

**Table 1.2.** Resource- and management-based animal welfare indicators included in the assessment protocols of the German Association for Technology and Structures in Agriculture (KTBL) (Brinkmann et al., 2016), the QM-Milch e.V. (Flint et al., 2016), and the Welfare Quality® project (WQ) differentiated according to the measurement method used and the targeted animal welfare domains according to Mellor (2017). Indicators directly referring to calf welfare are shown in italic. Modified from Hayer et al. (2018).

| Indicator | Measurement | Domains | KTBL | QM-Milch | WQ |
|---|---|---|---|---|---|
| Water provision | ④ | ❶❷❸ ❺ | ✓ | ✓ | ✓ |
| Access to outdoor loafing area or pasture, no tethering | ④ | ❶❷ ❹❺ | – | ✓ | ✓ |
| *Disbudding/Dehorning* | ② | ❸❹❺ | – | ✓ | ✓ |
| Cow-to-cubicle ratio | ④ | ❷❸❹❺ | – | ✓ | – |
| Cow-to-feeding place ratio | ④ | ❶❷❸❹❺ | – | ✓ | – |
| *Calving pen* | ④ | ❷❸❹❺ | – | ✓ | – |
| Special needs area | ④ | ❷❸❹❺ | – | ✓ | – |
| Calculated feeding diet | ④ | ❶ ❸❹❺ | – | ✓ | – |
| *Veterinary supervision* | ④ | ❶❷❸❹❺ | – | ✓ | – |
| *Provision of colostrum, feed, and water to calves* | ④ | ❶❷❸❹❺ | – | ✓ | – |
| *Hygiene of single calf housings* | ④ | ❷❸❹❺ | – | ✓ | – |
| Bedding material | ③ | ❷❸❹❺ | – | ✓ | – |
| Cow comfort installations | ③ | ❷❸❹❺ | – | ✓ | – |
| Treatments with hormones | ③ | ❸❹❺ | – | ✓ | – |
| Amount of antibiotic dry offs | ③ | ❸ | – | ✓ | – |
| Maintenance of milking parlor | ③ | ❷❸ ❺ | – | ✓ | – |
| *Targeted antibiotic treatments* | ③ | ❸ ❺ | – | ✓ | – |
| Cleanliness of water points | ③ | ❶❷❸❹❺ | – | – | ✓ |
| *Tail docking* | ③ | ❸❹❺ | – | – | ✓ |

**Measurement:**
① = Subjective estimation
② = Evaluation of selected animals
③ = Evaluation of all animals
④ = Analysis of measurement records

**The Five Domains of animal welfare:**
❶ = Nutrition
❷ = Environment
❸ = Health
❹ = Behavior
❺ = Mental State

**Table 1.3.** Animal-based animal welfare indicators included in the assessment protocols of the German Association for Technology and Structures in Agriculture (KTBL) (Brinkmann et al., 2016), the QM-Milch e.V. (Flint et al., 2016), and the Welfare Quality® project (WQ), differentiated according to the measurement method used and the targeted animal welfare domains according to Mellor (2017). Indicators directly referring to calf welfare are shown in italic. Modified from Hayer et al. (2018).

| Indicator | Measurement | Domains | KTBL | QM-Milch | WQ |
|---|---|---|---|---|---|
| Milk SCC | ④ | ❶❷❸❹❺ | ✓ | ✓ | ✓ |
| Integument alterations | ② | ❷❸❹❺ | ✓ | ✓ | ✓ |
| Lameness | ② | ❷❸❹❺ | ✓ | ✓ | ✓ |
| *Dystocia* | ① | ❷❸❹❺ | ✓ | ✓ | ✓ |
| Fat to protein ratio of milk | ④ | ❶❺ | ✓ | ✓ | – |
| Longevity | ④ | ❶❷❸❺ | ✓ | ✓ | – |
| *Calf mortality* | ③ | ❸❺ | ✓ | ✓ | – |
| Hoof health | ② | ❷❸❹❺ | ✓ | ✓ | – |
| Body condition score | ② | ❶❷❸❹❺ | ✓ | – | ✓ |
| *Cleanliness of the animals* | ② | ❷❸❺ | ✓ | – | ✓ |
| Avoidance distance | ② | ❹❺ | ✓ | – | ✓ |
| Dairy cow mortality | ④ | ❸❺ | – | ✓ | ✓ |
| Total Mortality | ④ | ❸❺ | ✓ | – | – |
| Incidence of mastitis treatments | ④ | ❸❺ | ✓ | – | – |
| *Incidence of diarrhea treatments* | ④ | ❸❺ | ✓ | – | – |
| *Incidence of respiratory treatments* | ④ | ❸❺ | ✓ | – | – |
| Usage of cubicles | ③ | ❷❹❺ | ✓ | – | – |
| Standing up motion | ② | ❷❸❹❺ | ✓ | – | – |
| *Complications after disbudding* | ② | ❸❹❺ | ✓ | – | – |
| *Cross suckling in calves* | ② | ❶❷❸❹❺ | ✓ | – | – |
| *Nesting score* | ② | ❷❸❹❺ | ✓ | – | – |
| The time needed to lie down | ② | ❷❸❹❺ | – | – | ✓ |
| Collisions with housing equipment | ② | ❷❸❹❺ | – | – | ✓ |
| Animals lying outside lying area | ② | ❷❹❺ | – | – | ✓ |
| Coughing | ② | ❷❸❺ | – | – | ✓ |
| Nasal discharge | ② | ❷❸❺ | – | – | ✓ |
| Ocular discharge | ② | ❷❸❺ | – | – | ✓ |
| Hampered respiration | ② | ❷❸❺ | – | – | ✓ |
| Diarrhea | ② | ❶❷❸❺ | – | – | ✓ |
| Vulvar discharge | ② | ❷❸❺ | – | – | ✓ |
| Downer cows | ② | ❶❷❸❹❺ | – | – | ✓ |
| Agonistic behavior | ② | ❷❸❹❺ | – | – | ✓ |
| Qualitative behavior assessment | ② | ❹❺ | – | – | ✓ |

**Measurement:**
① = Subjective estimation
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In 2009, the Welfare Quality® Project (WQ) also developed protocols for animal welfare assessments, with a specific focus on animal-based indicators. The EC launched the project in 2004 to meet growing consumer demand for higher farm animal welfare. Using a scientific approach, animal welfare indicator protocols, based on all stakeholders' views, were created for cattle, pigs, poultry, and laying hens (Botreau et al., 2009; Welfare Quality®, 2009; Hayer et al., 2018). The protocols were developed to provide farmers a comprehensive picture of their animals' welfare, facilitate policymaking, certify husbandry systems, and inform stakeholders and consumers (Botreau et al., 2009). Unlike the other assessment systems (KTBL, QM-Milch), the protocol was intended to be used by trained auditors rather than farmers (Welfare Quality®, 2009). On the one hand, the scientific community has widely appreciated the Welfare Quality assessment protocols and applied them in research settings (de Vries et al., 2013; Czycholl et al., 2016; Friedrich et al., 2019). On the other hand, the protocols have been criticized for being too time-consuming (Heath et al., 2014), focusing too much on single factors such as drinkers or access to pasture (de Vries et al., 2013), lacking reliability (Czycholl et al., 2016), or barely considering dairy calves (Barry et al., 2019b).

The indicators of all three protocols for dairy farms are presented in Tables 1.2 and 1.3. All three described assessment systems differ in their aims, design, and application and have certain advantages and disadvantages. Nevertheless, no welfare assessment protocol for dairy calves that includes a combination of resource-, management-, and animal-based indicators for use by farmers has yet been published and evaluated. Additionally, certain animal welfare aspects are missing in all protocols (Table 1.4). While limiting the number of indicators in animal welfare assessments increases their general applicability, it also diverts attention from improving animal welfare aspects that are not included (de Vries et al., 2013; Heath et al., 2014).

**Table 1.4.** Aspects of animal welfare that are currently missing in existing calf welfare assessment protocols for calves, differentiated by the targeted animal welfare domains, according to Mellor (2017).

| Animal welfare aspect | Domains | Reference |
|---|---|---|
| Pain during and after ear tagging | ❸❹❺ | Johnston and Edwards (1996), Lomax et al. (2017), Turner et al. (2020b) |
| Pain during and after removal of supernumerary teats | ❸❹❺ | DFC-NFACC (2009), Roberts and Fishwick (2010), Santman-Berends et al. (2012) |
| Navel disinfection and inflammation | ❸❹❺ | Grover and Godden (2010), Jorgensen et al. (2017) |
| Body temperature (e.g., heat stress, disease detection) | ❷❸ ❺ | McGuirk and Peek (2014), Kim et al. (2018) |
| Separation of calf and dam | ❶❷❸❹❺ | Gulliksen et al. (2009), Donat et al. (2016), Godden et al. (2019) |
| Social contact of calves with peers | ❶❷❸❹❺, | BMJV (2001), Jensen and Larsen (2014), Costa et al. (2019) |
| Limited use of mechanical calf puller | ❸❹❺ | Schuh and Killeen (1988), Lange et al. (2019), Pearson et al. (2020) |
| Hygiene of feeding equipment | ❶❷❸ ❺ | Maunsell and Donovan (2008), Trotz-Williams et al. (2008), Heinemann et al. (2021) |
| Handling of calves/ good stockmanship | ❷❸❹❺ | de Passillé and Rushen (2005), Lensink et al. (2000) |
| Colostrum volume & quality | ❶ ❸❹❺ | Godden et al. (2019) |
| Differentiation between male and female calves | ❶❷❸❹❺ | DFC-NFACC (2009), Franco et al. (2014), Bellamy (2017), Renaud et al. (2017) |
| Feeding of waste milk | ❶ ❸ ❺ | Aust et al. (2013), Barry et al. (2020), Heinemann et al. (2021) |

**The Five Domains of animal welfare:**
❶ = Nutrition
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## 1.5. Research aims and outline of the thesis

As elaborated in the previous chapters, dairy calf welfare is complex but highly relevant. In contrast, several recent international studies indicate that the animal welfare of calves is of lower priority in dairy farm management (Mee, 2020). However, no information is available on dairy calf management in Germany, nor on farmers' views on the welfare of their calves. A survey of calf management and farmers' views on welfare is necessary to assess the current status quo and identify potential challenges for implementing recommendations. These aspects will be addressed in chapter 2.

Painful procedures are of particular interest in the discussion on farm animal welfare because they are performed deliberately and directly affect welfare. However, in contrast to castration and dehorning of calves, painful procedures such as removing supernumerary teats or ear tagging have been only marginally researched. Ear tagging, which is the basis of animal identification and traceability in cattle, is scarcely researched even though it must be performed on every calf. More specifically, there is a lack of data on the prevalence of wound lesions associated with ear tagging and management recommendations to minimize adverse effects. Thus, the objective of chapter 3was to evaluate these factors for ear tag lesions in detail.

Animal welfare assessments function as a foundation for on-farm decision-making and animal welfare improvements. However, current animal welfare assessment protocols either exclude dairy calves or focus on indicators of one category (resource-, management-, or animal-based indicators) and omit important animal welfare aspects. A combination of management-based indicators with resource- and animal-based indicators, which allows the farmers to identify the welfare of their animals and at the same time derive possibilities for improvement, is still needed. Initially, it is necessary to identify influencing factors such as climatic conditions during the assessment or animal characteristics to establish the basis for using the protocol, increase reliability, and support farmers in their decision-making. Testing potential resource- and animal-based indicators and identifying influential factors was the aim of the fourth chapter.

Behavioral animal welfare indicators that include positive animal welfare aspects have received more attention in recent years. However, protocols for welfare assessment on dairy farms only include behavioral tests for adult dairy cows. Behavioral tests for calves have been used in research on single-housed calves, but rarely on group-housed calves and not by farmers. The study outlined in chapter 5 aimed to evaluate the applicability of behavioral tests for group-housed calves in self-assessments.

In chapter 6, the results of all four individual studies will be discussed with each other and other studies. In addition, other approaches to improve the welfare of dairy calves will be elaborated.

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# 2. Implementation of management recommendations in unweaned dairy calves in western Germany and associated challenges.

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## 2.1. Abstract

To improve the welfare of livestock, it is important to assess management practices on farms and to identify areas where current scientific recommendations are rarely implemented. Differences in the implementation of recommendations might be explained by the individual farm and the characteristics of respondents and their attitude towards animal welfare. Hence, the aim of this study was to assess dairy calf management practices, compare them with current scientific recommendations, and to explore factors that influence implementation of the recommended management practices. A 1.5-h interview was performed with stockpersons on 42 dairy farms (mean herd size ± SD = 149.9 ± 16.6 cows) distributed across western Germany in 2018 to 2019. We observed that the management of unweaned calves varied greatly from farm to farm in aspects such as milk feeding protocols; timing of grouping and disbudding; and access to water, roughage, and concentrate. Major deviations from management recommendations were (1) cleaning calving pen only by removal of bedding without a following disinfection prior to restocking on 23.8% farms, cleaning of teat buckets without detergents and disinfection (23.8 and 11.9% of farms, respectively), and failure to disinfect navels (29.3% of farms); (2) separating calf and dam after only 5 to 8 h p.p. for calving at night in 97.6% farms and unchecked colostrum quality by 23.8% of survey respondents; (3) feeding waste milk by 72.4% of the farms surveyed; and (4) removing supernumerary teats and disbudding without local anesthesia (90% and 80% farms surveyed, respectively). The number of implemented recommendations on the farms surveyed correlated with who was responsible for calf rearing and whether prioritizing animal welfare was considered important by the respondents. This study indicates that limitations of individual housing systems, time management, the stockperson’s knowledge, and the stockperson’s ability to relate to animals posed challenges in implementation of the recommendations. Further research on challenges in calf management and how to overcome those would be helpful to improve calves’ welfare in current husbandry systems.

***Key words:*** animal welfare, farm management, survey, stockperson attitude

## 2.2. Introduction

The rearing of dairy calves has received more attention in recent years from scientists and consumers, with common management practices being challenged (Jensen and Larsen, 2014; Renaud et al., 2017; Costa et al., 2019). However, even longstanding recommendations, such as pain relief for painful procedures (e.g., disbudding) or the supply of colostrum, retain their importance, as their full implementation is still limited (Shivley et al., 2018; Staněk et al., 2018; Winder et al., 2018). Surveys on the management of dairy calves can provide valuable information on the adoption of proven management practices that improve calf welfare on dairy farms. To date, these types of surveys have been launched in Canada (Vasseur et al., 2010), Czech Republic (Stanek et al., 2014), Austria (Klein-Jöbstl et al., 2015), the United States (Urie et al., 2018), and Ireland (Barry et al., 2020). However, to our knowledge no such type of survey has been done in Germany. In contrast to many other countries, Germany animal welfare legislation existed even before the European Union passed general regulations in 1998. The welfare of all animals is generally covered by the German Animal Welfare Act (BMJV, 1972); additional legal demands exist for calves (but not for adult cattle), laying hens, broilers, pigs, and rabbits (BMJV, 2001), which often exceed the EU regulations (Vogeler, 2019). Surveys, especially those that address sensitive topics, such as violation of animal welfare law or standards, are questioned in the sense that respondents might provide false information to avoid exposing themselves to criticism by the interviewer (Staněk et al., 2014). Particularly in personal interviews, the relationship and interaction between researcher and respondent influences the answers given (Kuzmanić, 2009). Using already existing personal relationships allows researcher access to additional resources in comparison to traditional interviews (Garton and Copland, 2010), which might help to address sensitive topics such as animal welfare.

Identifying management practices that are widely implemented and those that are seldom applied can be useful to shift the focus of future research to investigate why farmers may not implement those recommendations. Ritter et al. (2017) classified reasons for the implementation or failure of implementation of recommendations for strategies to prevent infectious diseases into the following: “problem awareness and perceived responsibility”, “farmers characteristics”, “effectiveness of proposed changes”, “perceived abilities to make changes” and “benefits and disadvantages of recommendations”. This classification of implementation of recommendations for strategies of infectious disease prevention is arguably also applicable to calf management decisions because both fields are primarily preventive and usually have no direct measurable value. The effect of stockperson characteristics, such as their knowledge or attitude toward animals on the handling and performance of calves has already been partly shown (Lensink et al., 2000).

The objective of this study was to investigate management practices toward unweaned dairy calves, the implementation of recommendations into practice and associated challenges in western German dairy farms. Furthermore, we analyzed the effect of farm characteristics and the attitude of the survey respondent toward animal welfare on the implementation of recommendations. We hypothesized that survey respondents with higher levels of education or those who consider animal welfare to be important have implemented more scientific recommendations in their calf management.

## 2.3. Material and Methods

Our study was conducted in accordance with ethical standards, the data privacy agreement of the University of Bonn (University of Bonn, 38/2018) and with federal and institutional animal use guidelines (FF AZ 01K 1901 201912).

### 2.3.1. Farm selection

Characteristics of German dairy farms vary by region, including use of different breeds as well as farm size and structure. This study focused on the Rhineland-Palatinate and North Rhine-Westphalia regions which have approximately 1,800 and 5,600 dairy farms, respectively. The average herd size in these regions is 63 and 74 cows, respectively (BMEL, 2019). Previous work has shown that farmers might be reluctant to discuss issues that fall under the EU regulations governing animal welfare (Staněk et al., 2014). Therefore, farms were only included in the study if they had participated in a previous study administered by the University of Bonn. After an initial telephone conversation explaining the study objectives with the farm managers of 45 farms located in these 2 regions, 42 farms (n = 22 in Rhineland-Palatinate and n = 20 North Rhine-Westphalia) agreed to participate in the study. All farms were then visited by 2 trained investigators between November 2018 and December 2019.

### 2.3.2. Structured Guided Interview

For the composition of the interview, we included animal welfare aspects from international, and national guidelines (e.g., EFSA, 2006; DFC-NFACC, 2009; FARM, 2017) as well as German legislation. The interview was structured into farm characteristics, 5 aspects of dairy calf management (calving management, colostrum management, housing and transport, calf feeding, and painful procedures), and stockpersons’ opinion on animal welfare (Supplemental

Table S7.1). In total, the interview contained 98 questions. The options to answer the questions were qualitatively nominal (e.g., yes or no), qualitatively ordinal (e.g., educational level), continuous (e.g., number of cows), free text statements, or a ten-point numerical scale (1 = not important at all to 10 = extremely important). For each question on dairy calf management, the interview also provided a free text space if the respondent wanted to add something or to comment on his or her answers (Supplemental Table S7.2). The interview was tested on 3 farms, was subsequently revised, and finally took (on average) 90 min. German dairy farms sell calves that are not kept for replacing dairy cows for either beef or veal production (earliest 14 d of age). In accordance with similar studies (Klein-Jöbstl et al., 2015; Barry et al., 2020), questions addressed the management of all calves on farm (mainly heifer calves) except for differences in feeding and painful procedures (i.e., castration) that were exclusive to male calves.

On arrival, the investigators requested to speak to the farmer or the stockperson primarily responsible for calf rearing. An interview guide (Supplemental Table S7.1) was used to standardize the questions across farms. In cases where a question was misunderstood by the stockperson, the question was reworded to provide additional clarity. The interview was conducted by the investigator that had initially contacted the farm to determine if they would be willing to participate in the study. Specific information was extracted from open questions on dairy calf management (e.g., data on milk-feeding plans). Answers to open questions regarding the attitude of respondents toward animal welfare were coded based on a self-developed data- and theory-driven codebook by the same person according to the procedure described by DeCuir-Gunby et al. (2011). For example, the indicators given to determine the well-being of calves "romping in the barn" and "playing together" were coded as "playing behavior”.

### 2.3.3. Assessment of Housing on Farms

Following completion of the face-to-face interview, the 2 trained investigators visually assessed the calf facilities. Recorded information included the housing system (e.g., single, pair or group housing), the housing position, the feeding implements (e.g., water and feeding troughs) in single and group housing, as well as the possibility of calves having social contact to adjacent calves (Supplemental Table S7.1). The assessment of the husbandry was performed without the presence of the stockperson.

### 2.3.4. Data Analysis

The completed interviews and calf facility inspection protocols were individually examined for missing values or aberrant results. Data were descriptively analyzed using the FREQ and MEANS procedures of SAS (version 9.4, SAS Institute Inc.) for categorial and continuous variables, respectively. Data were described as percentages of respondents who gave a certain answer for qualitative questions, and quantitative questions were described using the minimum, 25th percentile, median, 75th percentile, maximum values, as well as the means with standard deviation.

The results of the interview were compared with current international and national recommendations (Supplemental Table S7.1). To determine a general degree of implementation, each management practice was simply weighted (0 = recommendation not implemented or 1 = recommendation implemented). After weighting, the weighted recommendations were summed and the average implementation rate was calculated (sum of recommendations divided by number of weighted recommendations). Spearman rank correlations between the implementation rate and the recorded respondent and farm characteristics, as well as the answers on the qualitative questions about the mindset of the respondent toward animal welfare, were determined by the CORR procedure of SAS. The correlations were considered statistically significant at $P < 0.05$ with $0.05 < P < 0.1$ indicating a statistical tendency.

## 2.4. Results and Discussion

### 2.4.1. Farm Characteristics

The average number of lactating dairy cows on the assessed farms was 150 ± 16.6 cows, which is higher than the average herd size in Rhineland-Palatinate (63 cows) and North Rhine-Westphalia (74 cows) (BMEL, 2019). Further information on farm and respondents' characteristics is shown in Table 2.1. The average number of stockpersons working on the dairy farms was 4.0 (ranging from 2–10 stockpersons). Most farms preferred sharing the responsibility of calf rearing among several persons (61.9%), while on 38.1% farms only one person oversaw calf rearing. The age of the surveyed persons was on average38 ± 12.6 yr. Formal animal welfare training was provided most often by the Agriculture Insurance Association, followed by information conveyed by veterinarians, seminars or agricultural schools (Supplemental Table S7.2). Additional training regarding animal welfare was discussed as an effective method to ensure good handling of animals and therefore less stress for the animals (Coleman and Hemsworth, 2014). In a previous report de Passillé and Rushen (2005) argued that instead of monitoring animal behavior, training in animal handling may be the most effective and efficient method to ensure good stockmanship on farms.

**Table 2.1.** Reported farm and stockpersons' characteristics in western German dairy farms in comparison with German farms in general (n = 42).

| Variable | Category | Respondents, % (n) | German distribution, % |
|---|---|---|---|
| Farm structure | Family-owned | 97.6 (41) | 88.6[1] |
| | Not family-owned | 2.4 ( 1) | 11.4[1] |
| Used breed | Holstein-Friesian | 71.4 (30) | 56.1[2] |
| | Simmental | 4.8 ( 2) | 25.3[2] |
| | Brown Swiss | 2.4 ( 1) | 3.7[2] |
| | Mixed herd | 21.4 ( 9) | 5.1[2] |
| Person responsible for calf rearing[3] | Farmer | 59.5 (25) | NA[4] |
| | Worker | 45.2 (19) | NA |
| | Spouse | 28.6 (12) | NA |
| | Children | 28.6 (12) | NA |
| | Temporary staff | 9.5 ( 4) | NA |
| Sex of stockperson | Male | 85.7 (36) | 63.7[1] |
| | Female | 14.3 ( 6) | 36.3[1] |
| Educational level of stockperson | No agricultural education | 9.5 ( 4) | 34.6[1] |
| | Agricultural journeyman | 7.1 ( 3) | 21.6[1] |
| | One-year agricultural college | 42.9 (18) | 12.1[1] |
| | Agricultural master craftsmen | 21.4 ( 9) | 24.1[1] |
| | University degree in agriculture | 19.1 ( 8) | 7.7[1] |
| Animal welfare training of stockperson | Yes | 61.9 (26) | NA |
| | No | 38.1 (16) | NA |

[1]Source: Federal Statistical Office (2017).
[2]Source: BMEL (2020).
[3]Multiple answers possible.
[4]NA = not available.

Regular treatments of unweaned calves were given by the veterinarian on 54.8% of the farms; most of the treatments were vaccination against respiratory diseases, bluetongue disease or *Trichophyton verrucosum* infection (Supplemental Table S7.2). On 40.5% and 35.7% of the farms, respectively, the veterinarian or other consultants were consulted on a regular basis. Good cooperation with the veterinarian has been linked to an increase in vaccination of dairy calves (Renaud et al., 2017). However, most farms that used the consultancy of the veterinarian specified that they only called them in case of a sick calf for diagnosis and possible treatments (70.6%).

### 2.4.2. Reported Disease Incidence and Mortality

The reported incidence rate of dystocia, diarrhea and respiratory diseases showed a wide variation ranging from 1% to 20% yearly cases for dystocia and 0% to 100% yearly cases for diarrhea (Table 2.2), indicating that dystocia or diarrhea was a major issue on some farms, but other farms were not affected at all. Comparable numbers were gained by studies on diarrhea incidences in Sweden and Austria, where ranges were reported between 0% and 39.4% for Sweden and below 10% to over 75% for Austria (Lundborg et al., 2005; Klein-Jöbstl et al., 2015).

**Table 2.2.** Reported annual mortality rates and disease incidence for dystocia, diarrhea, and respiratory diseases in all suckling dairy calves in western German dairy farms (n = 42).

| | Reported incidence (%) | | | | |
|---|---|---|---|---|---|
| Impairment of health | Minimum | 25th percentile | Median | 75th percentile | Maximum |
| Dystocia | 1.0 | 2.1 | 5.0 | 7.9 | 20.0 |
| Diarrhea in unweaned calves | 0.0 | 5.0 | 12.5 | 30.0 | 100.0 |
| Respiratory tract disease in unweaned calves | 0.0 | 3.0 | 7.0 | 12.5 | 70.0 |
| Calf mortality in the first 14 d[1] | 0.0 | 2.0 | 3.5 | 5.0 | 15.0 |
| Calf mortality until weaning[2] | 1.0 | 3.0 | 5.0 | 7.1 | 20.0 |

[1]Defined as calves born alive that died within the first 14 d of life.
[2]Defined as calves born alive that died in the nursing phase.

A similar variation can also be seen in mortality rates (Table 2.2). Most losses occurred during the first 14 d p.p. compared to the rest of the nursing period. A comparison of mortality rates between studies is difficult due to different mortality definitions, measurements and chosen periods of investigation (Johnson et al., 2011; Raboisson et al., 2013). Nevertheless, studies from different countries calculated a mortality rate between 5% and 10% for calves that can be considered unweaned (Johnson et al., 2011) with comparable ranges from zero calf losses to losses up to 25% during the nursing phase (Torsein et al., 2011; Raboisson et al., 2013; Klein-Jöbstl et al., 2015).

### 2.4.3. Calving Management

The time around calving is crucial for the health and welfare of the dam and the newborn calf (Gulliksen et al., 2009; Klein-Jöbstl et al., 2014). Therefore, it is necessary to provide the calving cow a stress-free environment with a minimized risk of disease transmission (Gulliksen et al., 2009; Torsein et al., 2011; Donat et al., 2016). All the farms surveyed had a dedicated calving pen, similar to findings in the Czech Republic (Staněk et al., 2014) or North Germany

(Heuwieser et al., 2010); whereas in Canada, Austria or the United States having a dedicated calving pen is not as common (Vasseur et al., 2010; Klein-Jöbstl et al., 2015; USDA, 2016).

**Table 2.3.** Reported management of calving pens and postnatal husbandry on western German dairy farms (n = 42).

| Variable | Category[1] | n (%) |
|---|---|---|
| Use of calving pens (n = 42) | Yes | 42 (100.0) |
| | No | 0 ( 0.0) |
| Number of calving pens (n = 42) | One | 22 ( 52.4) |
| | More than one | 20 ( 47.6) |
| Housing of sick cows in calving pens (n = 42) | Yes | 25 ( 59.5) |
| | No | 17 ( 40.5) |
| Bedding material in calving pens (n = 42) | Straw | 42 (100.0) |
| | Others | 0 ( 0.0) |
| Cleaning of calving pens (n = 42) | Time-based | 35 ( 83.3) |
| | After every calving | 3 ( 7.1) |
| | Irregularly | 4 ( 9.5) |
| Cleaning interval for calving pens (n = 35) | ≤ 1 mo | 20 ( 57.1) |
| | 1–3 mo | 12 ( 34.3) |
| | > 3 mo | 3 ( 8.6) |
| Cleaning method for calving pens (n = 42) | Only removal of bedding | 32 ( 76.2) |
| | Use of high-pressure cleaner | 10 ( 23.8) |
| Disinfection of the calving pens after cleaning (n = 42) | Yes | 9 ( 21.4) |
| | No | 33 ( 82.5) |
| Documentation of dystocia (n = 42) | Yes | 15 ( 35.7) |
| | No | 27 ( 64.3) |
| Usage of mechanical calf puller (n = 42) | Never | 3 ( 7.1) |
| | For severe dystocia only | 33 ( 78.6) |
| | For dystocia only | 4 ( 9.5) |
| | Not exclusively for dystocia | 2 ( 4.8) |
| Separation from the dam when calving during the day (n = 42) | < 1 h | 8 ( 19.1) |
| | 1–4 h | 9 ( 21.4) |
| | 5–12 h | 14 ( 33.3) |
| | 12–24 h | 8 ( 19.1) |
| | > 1 d | 3 ( 7.1) |
| Separation from the dam when calving at night (n = 42) | < 1 h | 1 ( 2.4) |
| | 1–4 h | 0 ( 0.0) |
| | 5–12 h | 30 ( 71.4) |
| | 12–24 h | 6 ( 14.3) |
| | > 1 d | 5 ( 11.9) |

[1]Scientific recommendations and international and national law are shown in Supplemental Table S7.1

In the debate on individual or group calving pens, some studies conclude that it is more a question of proper management, occupation and hygiene of the pens (Pithua et al., 2009; Klein-Jöbstl et al., 2014). Contamination of calving pens by keeping sick cows in these areas could be an underlying driver for disease transmission and was practiced by more than half of the surveyed farms, which is in line with findings from Canada (Vasseur et al., 2010) with 52.8%

and the United States (USDA, 2016) with 40.9% of the farms. Donat et al. (2016) showed that hygiene measures, such as disinfection of calving pens, are effective tools to disrupt infection chains between adult cows and newborn calves. Furthermore, farms with lower prevalence of calf diarrhea were more likely to clean their calving pen after every calving (Klein-Jöbstl et al., 2014). In contrast, just a small number of farms in this study cleaned the calving pen properly by using a high-pressure cleaner and disinfecting afterwards (Table 2.3), which is similar to results from Austria and Ireland (Klein-Jöbstl et al., 2015; Cummins et al., 2016).

The incorrect use of mechanical calf pullers can raise the risk of injuries for the dam, as well as for the calf, and thus should only be used in cases of severe dystocia (Schuh and Killeen, 1988; Lange et al., 2019). However, 9.5% of the farms used a mechanical calf puller for dystocia in general, and 4.8% farms used them also for normal calving. The stated rate of dystocia on the farms surveyed varied largely between farms (Table 2.2) and possibly mirrored the different extent of documentation and analysis of numbers on the farms (Table 2.3).

The time of separation of dam and calf differed between daytime and nighttime birth, as most of the farms had longer cow-calf contact during nighttime calving (Table 2.3). For conventional early separation of dam and calf, prompt separation is favored by some authors as it enables a guaranteed provision of sufficient high-quality colostrum and leads to reduced behavioral responses by dam and calf (Weary and Chua, 2000; Gulliksen et al., 2009; Godden et al., 2019). Some stockpersons indicated that the timing of the separation was dependent on the next milking time and not on a specific period (Supplemental Table S7.2).

### 2.4.4. Colostrum Management

Colostrum is widely considered the most important single influence on calf health and survival (Gulliksen et al., 2009; Godden et al., 2019). Therefore, special attention should be paid to provide calves with high-quality colostrum as soon as possible after birth (Shivley et al., 2018; Godden et al., 2019). Eighty percent of farms surveyed reported ensuring a first colostrum intake in the first 6 h p.p. (Table 2.4), which might be exaggerated as separation from dam after calving is done later, especially for calving at night. A similar bias was found by Vasseur et al. (2010), where similar responses for colostrum provision were given (time of separation later than 6 h p.p. by 94.8% of respondents), but the level of surveillance during the night was low. Less than a quarter checked the colostrum quality (23.8%), even though simple methods for measuring Ig concentration, such as refractometers, are available (Buczinski and Vandeweerd, 2016). Surveys from other countries have reported that the use of quality control tools is also rather low (Vasseur et al., 2010; Staněk et al., 2014; Klein-Jöbstl et al., 2015; USDA, 2016).

**Table 2.4.** Reported colostrum feeding management on western German dairy farms (n = 42).

| Variable | Category[1] | n (%) |
|---|---|---|
| Control of colostrum intake (n = 42) | Yes | 39 (92.9) |
| | No | 3 ( 7.1) |
| Colostrum feeding method[2] (n = 42) | Dam | 21 (50.0) |
| | Bottle | 17 (40.5) |
| | Esophageal tube | 10 (23.8) |
| | Bucket with artificial teat | 14 (33.3) |
| First colostrum meal (n = 40) | > 1 h p.p. | 29 (72.5) |
| | 1–6 h p.p. | 3 ( 7.5) |
| | Next milking time | 8 (20.0) |
| Frozen colostrum stocks (n = 41) | Yes | 32 (78.0) |
| | No | 9 (22.0) |
| Colostrum from primiparous cows fed (n = 42) | Yes | 35 (83.3) |
| | No | 7 (16.7) |
| Checking colostrum quality (n = 42) | Yes | 10 (23.8) |
| | No | 32 (76.2) |
| Amount of colostrum fed[2] (n = 40) | Restrictive | 29 (72.5) |
| | Ad libitum | 11 (27.5) |
| | Minimum 3.0 L | 14 (35.0) |

[1]Scientific recommendations and international and national law are shown in Supplemental Table S7.1
[2]Multiple answers possible

Although feeding calves sufficient colostrum in the first 6 h p.p. is important (Gulliksen et al., 2009; Godden et al., 2019), only one-third (35.0%) reported feeding at least 3.0 L of colostrum for the first meal. The number of farms surveyed with recommended colostrum stocks was higher than in the US (49.3%; USDA, 2016) or Canada (32.2%; Vasseur et al., 2010), but similar to the Czech Republic (73.5%; Staněk et al., 2014) or Austria (72.7%; Klein-Jöbstl et al., 2015).

### 2.4.5. Housing and Transport

The farms that disinfect navels (68.3%) did this immediately after birth or as soon as possible, which has been shown to reduce umbilical infections (Grover and Godden, 2011). However, one farm disinfected the navel 4–12 h p.p. Almost all surveyed farms housed their calves in single houses during the first days, and in groups afterward (95.2%). A practice that has already been described as common in Germany but differs from the practice in the United States, Canada, or Czech Republic, where most calves are reared individually until weaning (Staněk et al., 2014; USDA, 2016; Winder et al., 2018;). Two of the farms housed calves in pairs for up to 3 weeks p.p. and moved them later into larger groups. Early pairing of calves can foster social behavior and performance in the weaning phase (Jensen and Larsen, 2014; Costa et al., 2015). Single housings of 31% of the farms were not designed to enable physical contact to adjacent calves, even though it is legally required (BMJV, 2001). Jensen and Larsen (2014) showed that with an increasing level of social contact, calves become less fearful, and that even visual and restricted tactile contact can be beneficial. The calves were kept in single or pair housing for a period of 16.9 ± 5.4 d (Figure 2.1).

Almost all the surveyed farms cleaned their single housing after every occupancy, which has been shown to reduce the occurrence of diarrhea caused by rotavirus (Bartels et al., 2010), and only 4.8% cleaned the single housing irregularly. The most common cleaning measure was cleaning with a high-pressure cleaner (90.5%). Additional cleaning agent was used by 7.1% of the farms surveyed, while one farm only rinsed the housing with water after removing the bedding material. A subsequent disinfection of the housing was carried out by 73.8% of all farms surveyed, either after each occupancy (80.6%) or less frequently (19.4%). Cleaning with high-pressure cleaner and detergents followed by disinfection can reduce the risk of disease transmission to newly housed calves (Johnson et al., 2011; Hancox et al., 2013). In a survey from Austria, 61.1% of respondents stated that they clean calf houses regularly, 42.3% used a high-pressure cleaner for cleaning and an additional 19.9% disinfected afterwards (Klein-Jöbstl et al., 2015). In total, most of the farms surveyed clean within a recommended interval but could improve their hygiene management by using cleaning agents.

Male dairy calves were held on 14% of farms for fattening and were sold on the other 86%. According to EU directives, the transport of calves is only permitted from the age of 14 d and is considered a stressful and health-challenging experience, which is why sufficient feeding before transport is particularly important (Fisher et al., 2014). Most of the farms stated that the sold calves were fed in the 6 h before the transport, except for 20% of farms surveyed. On 12.1% of the farms, the calves received additional electrolytes before transport, but these farms were only farms that already fed the calves 6 h before transport.

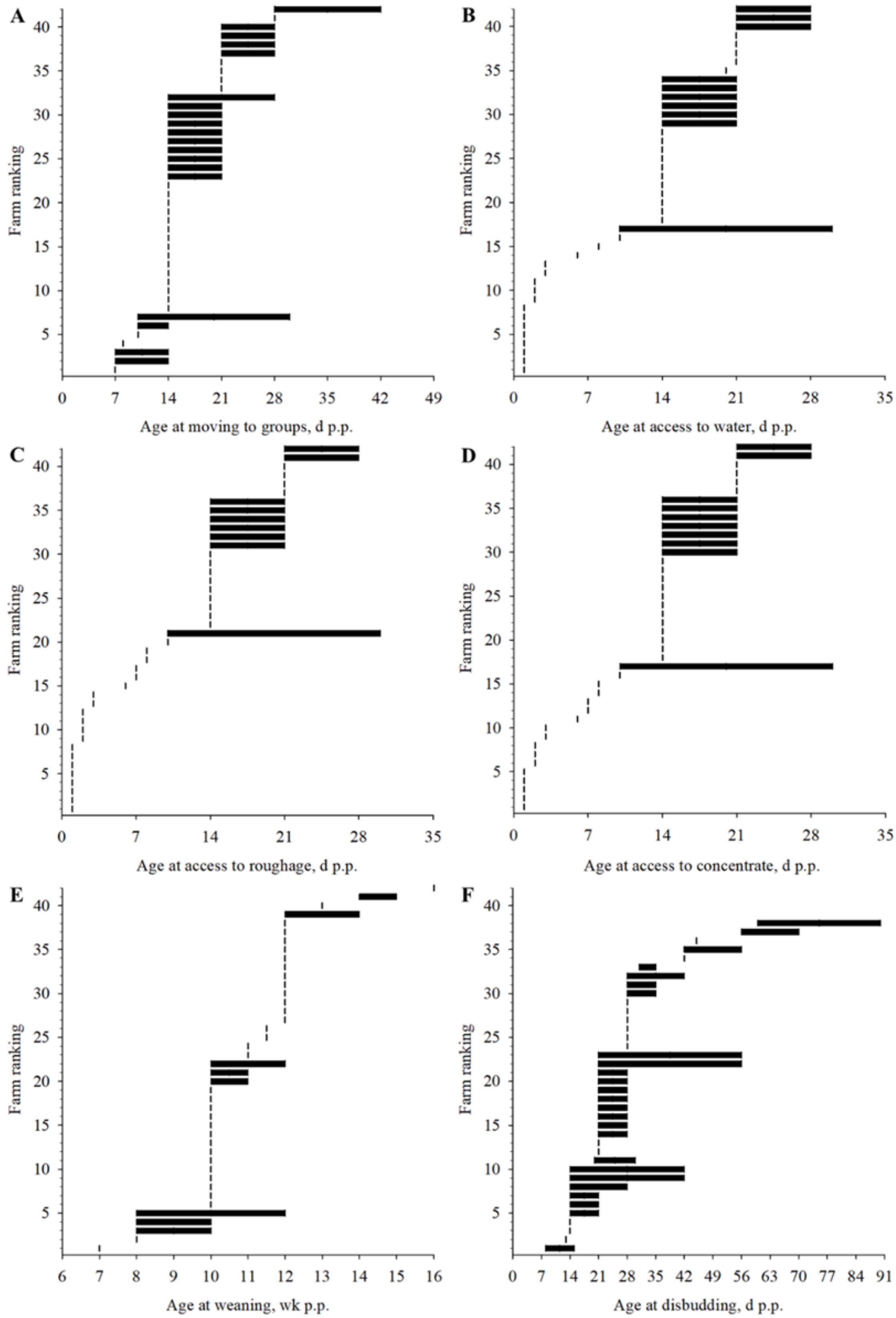


**Figure 2.1.** Reported age postpartum (p.p.) of dairy calves at moving to groups (A), at access to water (B), at access to roughage (C), at access to concentrate (D), at weaning (E) and at disbudding (F); the reported time frame is displayed as charts for periods or as strokes for exact dates. Farms are ranked from lowest initial age to highest age for each graph.

### 2.4.6. Calf Feeding

Providing unweaned dairy calves with sufficient feed has been recognized as a key animal welfare issue (Costa et al., 2019). Calf feeding management varied widely on the farms surveyed, as only 2 of the 42 farms surveyed used the same milk feeding plan (Supplemental Figures S7.1-S7.4). The range of feeding plans included fixed quantities of milk in 2 meals until weaning (n = 12), stepwise increase of volume fed (n = 19), high initial volumes of milk followed by a stepwise decrease (n = 8), and fluctuating milk volumes (n = 3). Calves can consume 12 L of milk or more per day in ad libitum feeding programs, whereas restricted milk allowance of 6 L and less (< 15% birth weight) milk equivalent per day is associated with physical signs of hunger and reduced weight gain (Rosenberger et al., 2017; Costa et al., 2019). Table 2.5 illustrates the distribution of responses on feeding management. Unpasteurized waste milk and milk from cows with high SCC were fed on more than half of the farms surveyed, despite the verified risks of selecting for antibiotic resistant bacteria (Aust et al., 2013). Other recommendations such as the usage of feeding implements that allow calves to suckle (Jensen 2003) were implemented widely. The average weaning age was 10.9 ± 1.6 weeks (Figure 2.1). Differentiation in feeding calves based on their sex seems to be common as male calves are fed less colostrum, which is provided later or only by suckling from the dam in the United States (Shivley et al., 2019), are fed less milk on some Canadian farms (Renaud et al., 2017), or fed waste milk more often in Austria (Klein-Jöbstl et al., 2015). Ten of the farms surveyed reported feeding less milk to male calves, while another 10 stated feeding them milk with SCC or waste milk instead of milk replacer or bulk milk.

Teat buckets were run through hygienic measures on all farms, but the sanitation interval and methods differed (Table 2.5). Similar results were found in Ireland with 24 to 34% of the farms cleaning the buckets with additional detergents, but less regularly (11–21% daily; Barry et al., 2019). Recently, Heinemann et al. (2020) found that teat buckets can have high bacterial burdens if they are not thoroughly cleaned.

The provision of solid feed in addition to milk is recommended, as early provision of solid feed has been shown to reduce mortality (Torsein et al., 2011), influence feeding behavior, and does not necessarily reduce feed intake after weaning (Khan et al., 2011; Miller-Cushon and DeVries, 2011). In total, water, roughage, and concentrate were provided relatively late (Figure 2.1), and often only in group housings (Table 2.5).

**Table 2.5.** Reported calf feeding management on western German dairy farms (n = 42).

| Variable | Category[1] | n (%) |
|---|---|---|
| Feeding calves an average of at least 6 L of milk per day (n = 42) | Yes | 31 ( 73.8) |
| | No | 11 ( 26.2) |
| Ad libitum milk (n = 42) | Yes | 5 ( 11.9) |
| | No | 37 ( 88.1) |
| Stepwise weaning phase in included in milk feeding plans (n = 42) | Yes | 17 ( 40.5) |
| | No | 25 ( 59.5) |
| Milk equivalent fed[2] (n = 42) | Whole milk | 35 ( 83.3) |
| | Milk replacer | 31 ( 73.8) |
| | Unpasteurized waste milk | 24 ( 57.1) |
| | Unpasteurized milk with high SCC | 23 ( 54.8) |
| Milk temperature (n = 42) | Warm | 42 (100.0) |
| | Cold | 0 ( 0.0) |
| Usage of milk acidifier (n = 42) | Yes | 14 ( 33.3) |
| | No | 28 ( 66.6) |
| Usage of milk additives (n = 42) | Yes | 9 ( 21.4) |
| | No | 33 ( 78.6) |
| Different feeding of male and female calves (n = 42) | Yes | 20 ( 47.6) |
| | No | 22 ( 52.4) |
| Feeding implement[2] (n = 42) | Teat buckets | 42 (100.0) |
| | Automatic milk-feeding system | 14 ( 33.3) |
| | Open buckets | 2 ( 4.8) |
| Cleaning interval of teat buckets (n = 42) | Twice a day | 11 ( 26.2) |
| | Once a day | 14 ( 33.3) |
| | Once a week | 5 ( 11.9) |
| | Less than once a week | 4 ( 9.5) |
| | After every calf | 8 ( 19.1) |
| Disabling of artificial teat for cleaning of teat buckets (n = 42) | Yes | 9 ( 21.4) |
| | No | 33 ( 82.5) |
| Teat buckets cleaning method[2] (n = 42) | Cold water | 20 ( 47.6) |
| | Warm water | 22 ( 52.4) |
| | Additional cleaning agent | 22 ( 26.3) |
| Disinfection of teat buckets (n = 42) | Yes | 5 ( 11.9) |
| | No | 37 ( 88.1) |
| Provision of water in single housings (n = 42) | Yes | 17 ( 40.5) |
| | No | 25 ( 59.5) |
| Provision of roughage in single housings (n = 42) | Yes | 17 ( 40.5) |
| | No | 25 ( 59.5) |
| Provision of concentrate in single housings (n = 42) | Yes | 11 ( 26.2) |
| | No | 31 ( 73.8) |

[1]Scientific recommendations and international and national law are shown in Supplemental Table S7.1
[2]Multiple answers possible

German law prescribes that calves have permanent access to roughage at an age of 8 d and permanent access to water at an age of 14 d (BMJV, 2001), which was disregarded by 54.8% of the surveyed farms for the provision of roughage and by 31.0% for the provision of water. Stockpersons might assume that water intake through milk consumption is sufficient. However, recent research has shown that calves with access to water from d 1 drank more milk, tended to have greater BW and heart girth preweaning and had increased digestibility and growth postweaning compared with calves without immediate access (Wickramasinghe et al., 2019).

**2.4.7. Painful Procedures**

Although many housing systems and management practices can compromise animal welfare, painful procedures are performed intentionally, and inevitably cause distress in calves. However, ear tagging, castration or dehorning are in some cases legally required or done to reduce health risks for stockpersons and livestock. In Germany, legal regulations require the identification and registration of newborn calves within the first 7 d p.p. with ear tagging being the only legal method for identification (BMJV, 2007). However, 2 farms stated that they disregarded this obligation by tagging the calves older than 7 d (4.9%). In addition to the benefits of an early identification and an unquestionable demand for monitoring, ear tagging should be considered a painful procedure because the calves show visible signs of pain following the treatment (Turner et al., 2020), and the ear tissue is damaged by the tags (Johnston and Edwards, 1996).

All farms visited renounced the castration of their male calves, which is most likely linked to established veal production chains and the high production of beef from bulls that contributes to 48.1% of the total beef production in Germany (Hocquette et al., 2018). Dehorning calves by disbudding when breeding toward a genetic hornless herd was common on the farms surveyed (Table 2.6). According to the German Animal Welfare Act, painful procedures are only allowed if they are necessary and anesthesia is administered. Even though the disbudding of calves below the age of 42 d is listed as an exception and is allowed without anesthesia, measures to reduce pain and suffering (such as sedation and anesthesia) must be applied in Germany (BMJV, 1972). Sedatives and analgesics can be given to the farmer by the veterinarian for administration under certain conditions, while all medical products for local anesthesia may only be applied directly by a veterinarian (BMJV, 1975).

**Table 2.6.** Reported management of disbudding and removal of supernumerary teats on western German dairy farms (n = 42).

| Variable | Category[1] | n (%) |
|---|---|---|
| Disbudding (n = 42) | Yes | 40 ( 95.2) |
| | No | 2 ( 4.8) |
| Use of polled sires (n = 42) | Yes | 35 ( 83.3) |
| | No | 7 ( 16.7) |
| Disbudding responsibility (n = 40) | Always the same person | 32 ( 80.0) |
| | Change of person | 8 ( 20.0) |
| Person performing disbudding[2] (n = 40) | Farm manager | 25 ( 62.5) |
| | Worker | 7 ( 17.5) |
| | Children | 8 ( 20.0) |
| | Spouse | 1 ( 2.5) |
| | Trainee | 4 ( 10.0) |
| | Veterinarian | 0 ( 0.0) |
| Method for disbudding (n = 40) | Hot iron disbudding | 40 (100.0) |
| | Chemical methods | 0 ( 0.0) |
| | Mechanical methods | 0 ( 0.0) |
| Calves disbudded at one time (n = 40) | Individually | 3 ( 7.5) |
| | In groups | 34 ( 85.0) |
| | Both | 3 ( 7.5) |
| Fixation of calves (n = 40) | Yes | 4 ( 10.0) |
| | No | 36 ( 90.0) |
| Veterinarian present while disbudding (n = 40) | Yes | 5 ( 12.5) |
| | No | 35 ( 87.5) |
| Sedatives for disbudding (n = 40 | Yes | 40 (100.0) |
| | No | 0 ( 0.0) |
| Analgesics for disbudding (n = 40) | Yes | 37 ( 92.5) |
| | No | 3 ( 7.5) |
| Local anesthesia for disbudding (n = 40) | Yes | 8 ( 20.0) |
| | No | 32 ( 80.0) |
| Removal of supernumerary teats (n = 42) | Yes | 20 ( 47.6) |
| | No | 22 ( 52.4) |
| Time of supernumerary teats removal (n = 20) | Directly after birth | 9 ( 45.0) |
| | While disbudding | 8 ( 40.0) |
| | While regrouping | 3 ( 15.0) |
| Veterinarian present for removal of teats (n = 20) | Yes | 2 ( 10.0) |
| | No | 18 ( 90.0) |
| Sedatives for removal of teats (n = 20) | Yes | 9 ( 45.0) |
| | No | 11 ( 55.0) |
| Analgesics for removal of teats (n = 20) | Yes | 8 ( 40.0) |
| | No | 12 ( 60.0) |
| Local anesthesia for removal of teats (n = 20) | Yes | 2 ( 10.0) |
| | No | 18 ( 90.0) |

[1]Scientific recommendations and international and national law are shown in Supplemental Table S7.1
[2]Multiple answers possible

On the farms surveyed, all calves are presumably disbudded in a state of sedation by an intramuscular injection of anesthetic (xylazine) before the disbudding. Almost all farms stated to provide analgesics for disbudding (92.5%, meloxicam). The use of sedative combined with local anesthesia and systematic analgesia is considered to eliminate acute pain (Stafford and Mellor, 2011), but was only performed by 17.1% of the farms. Nevertheless, the surveyed farms used pain medications more often compared with other countries, such as the Czech Republic (Staněk et al., 2018), the United States (Urie et al., 2018), or Canada (Vasseur et al., 2010). As most farms disbudded their calves in groups (Table 2.6), disbudding was mainly performed over a time span (Figure 2.1). The average age of disbudding in this study was 28.4 ± 12.7 d. In the US and the Czech Republic, calves were disbudded at a similar age (Staněk et al., 2018; Urie et al., 2018); however calves were disbudded at a later age in Canada (Vasseur et al., 2010). On 7.1% of the farms in this study, the stated minimum age at disbudding was already above the legal threshold, and 14.3% reported a maximum disbudding age of over 42 d.

Contrary to disbudding, the removal of supernumerary teats is not specifically mentioned in German regulations. Supernumerary teats are an inherited condition and, if left untreated, can lead to interference at milking or increase the risk of mastitis (Roberts and Fishwick, 2010). Almost half of the farms surveyed stated that they remove supernumerary teats in unweaned heifer calves (Table 2.6). The removal of supernumerary teats during disbudding allows calves to receive the benefits from pain medication for disbudding and the potential presence of a veterinarian. In Canada, teat removal is performed considerably later (median of 6.7 mo) and most often without pain mitigation (Vasseur et al., 2010).

### 2.4.8. Implementation of Scientific Recommendations

In total, 52 possible recommended management parameters were questioned during the farm visits (Supplementary Table S1). The average farm implemented 56.3% of the recommendations, ranging from 37.3% to 74.5%, indicating that even the best farms still had potential for improving their calf management (Figure 2.2). Recommendations that were rarely implemented (implementation rate < 33%) were (1) hygiene management practices, such as the proper cleaning and disinfection of calving pens, calf housings, and the feeding equipment, as well as the disinfection of navels directly after birth; (2) sufficient colostrum provision with few farms checking colostrum quality and a late separation of calf from the dam; (3) renouncing the feeding of waste milk and milk from cows with mastitis; and (4) disbudding calves in the first 3 weeks p.p. and the use of local anesthesia for the disbudding and supernumerary teat removal.

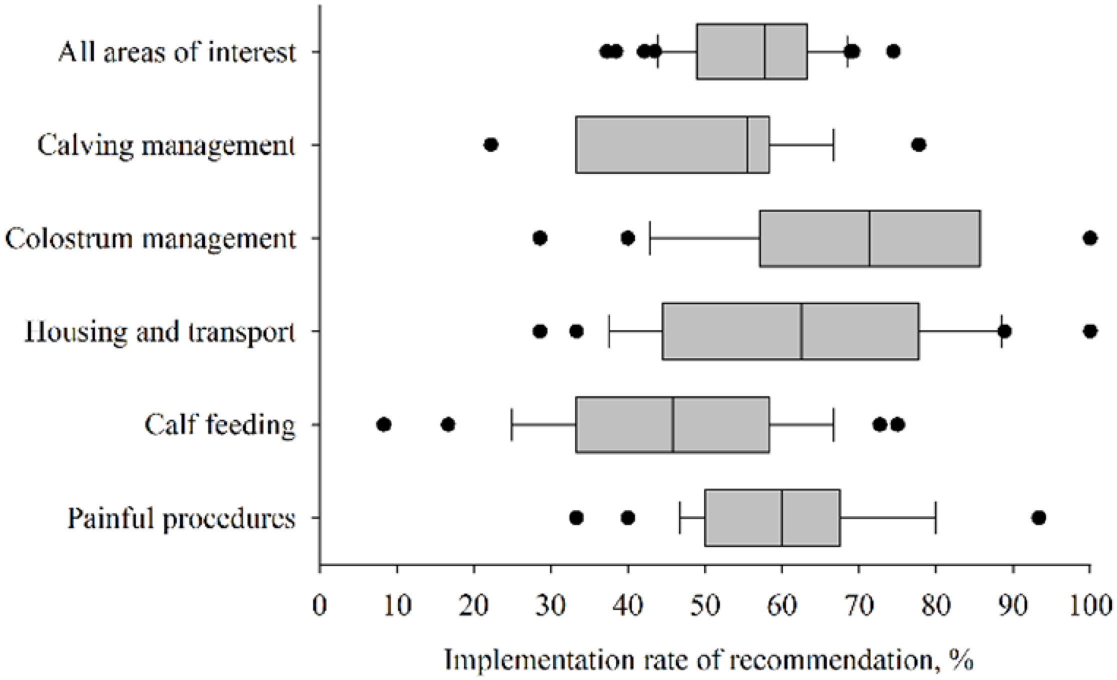


**Figure 2.2.** Rate of implementation for 52 calf management recommendations evaluated on western German dairy farms (n = 42) sorted by aspects of calf management (calving management, 9 recommendations; colostrum managements, 7 recommendations; housing and transport, 9 recommendations; calf feeding, 12 recommendations; painful procedures, 15 recommendations). The black line inside each box represents the median; lower and upper hinges represent the 25th and 75th percentiles, respectively. The whiskers end at the lowest and highest value that are not outliers. Outliers are shown as dots.

Surprisingly, most surveyed farms cleaned calving pens, single housings and teat buckets within a recommended interval (54.8%, 95.2% and 65% implementation rate, respectively) but used unrecommended techniques and rarely disinfected afterward. Heinemann et al. (2020) found in their study that dairy farmers were aware of hygiene weaknesses but did not try to improve as their mortality was rather low already. Nevertheless, even if mortality remains at a tolerable low level, which was not the case for most of our surveyed farms, proper hygienic measures should be implemented to minimize infection risks (Gulliksen et al., 2009; Torsein et al., 2011; Johnsen et al., 2021). Furthermore, disbudding was recognized as a painful procedure by the respondents to a certain extent, as all of them indicated to use medication to reduce pain, and 83.3% used polled sires, but total pain mitigation will be rarely achieved. Total pain mitigation requires the presence of a veterinarian, which is linked with higher costs and higher organizational effort, and thus might lead to low implementation of total pain mitigation. In Switzerland, administration of local anesthesia by trained and certified farmers is legal since 2008 and promise to increase the number of farmers using local anesthesia (Alsaaod et al., 2014).

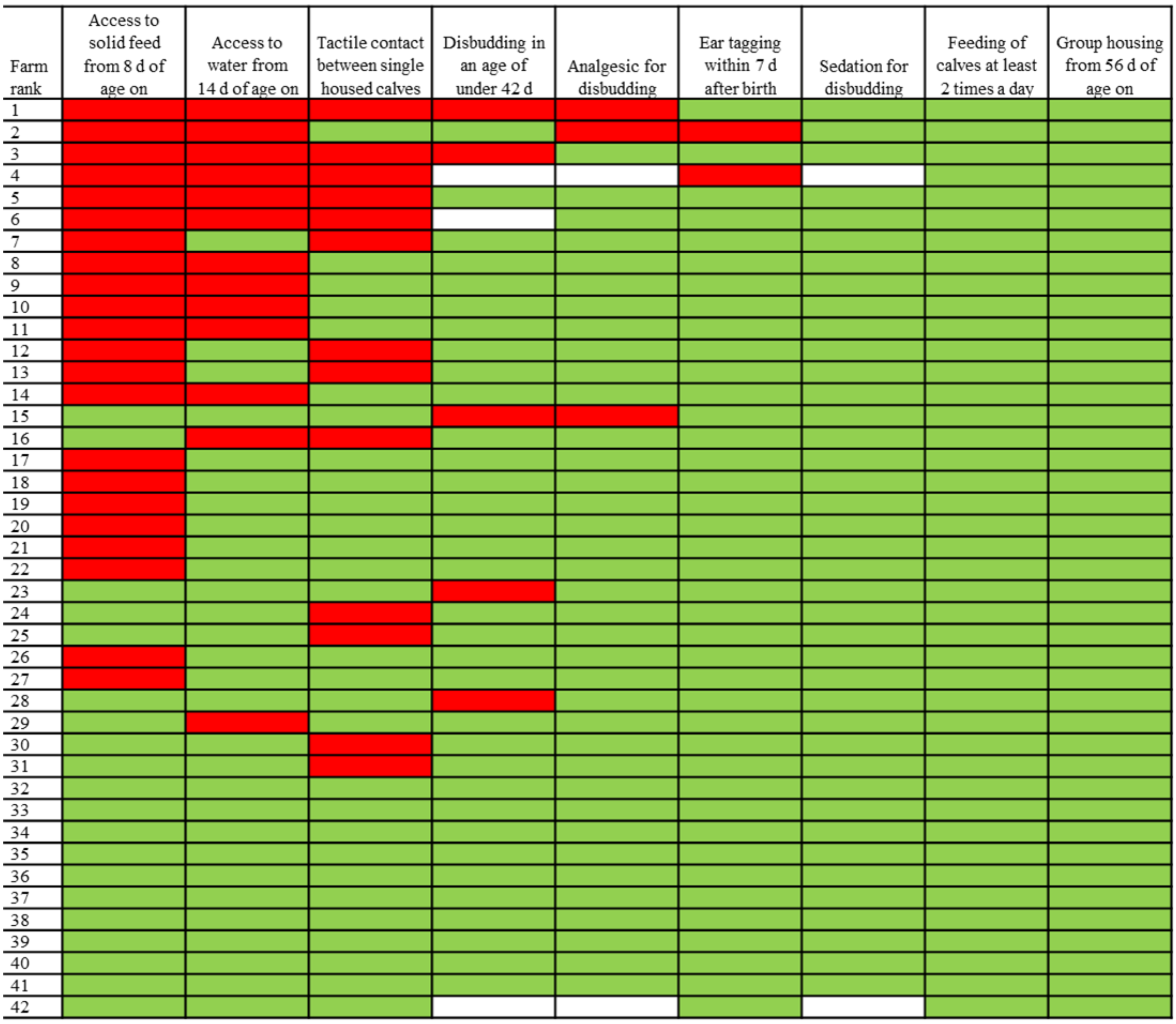


**Figure 2.3.** Implementation of assessed German calf rearing management regulations (green = implemented, red = not implemented; white = not assignable). Farms ranked according to the number of infringements. Sources: BMJV (2001) for access to solid feed from 8 d of age on, access to water from 14 d of age on, tactile contact between single housed calves, feeding of calves at least 2 times per day, and group housing from 56 d of age on; BMJV (1972) for disbudding in an age of under 42 d, analgesic for disbudding, sedation for disbudding; BMJV (2007) for ear tagging within 7 d after birth.

Partly included in the 52 evaluated recommendations were nine German legal regulations, of which only 3 were implemented on all farms (Figure 2.3). Especially the provision of solid feed from d 8, water from d 14 and the social contact between individually housed calves especially seemed to be a major challenge on some of the farms surveyed. One reason was the design of the used calf hutches and boxes, as some of them were not designed to enable contact between adjacent calves and were too small to attach water and feeding troughs. Furthermore, some farmers stated that they would provide solid feed if their single houses were under a roof and thereby protected from precipitation. A recent study conducted in Norway (Johnsen et al., 2021) found 16% of farmers failing to provide water in the first 21 d, which was also related to the lack of water supply in single housing. The lack of free access to water was associated with greater mortality rates in their study. Housing calves in groups earlier might be a solution to provide additional feed and water earlier due to limitations of the husbandry system. All changes in housing facilities require long-term monetary investments and major adaptions in working processes (Bergschmidt and Schrader, 2009; Ritter et al., 2017).

The total implementation rate was independent of age, sex, and educational background of the respondent, as well as herd size and number of stockpersons per farm. However, stockpersons with a higher level of educational background implemented significantly more recommendations in colostrum management (Table 2.7). Furthermore, sharing the responsibility with more persons tended to be positively correlated with the number of recommendations implemented. Farms with a hired worker responsible for calf rearing, implemented more recommendations into their management. In detail, farms with an employee who works in calf husbandry were more likely to feed colostrum early (r = 0.33, $P = 0.04$), to offer roughage early (r = 0.33, $P = 0.03$), to clean calving pens more often (r = 0.35, $P = 0.03$), to disinfect the navel more often (r = 0.37, $P = 0.02$) and to disbud calves more often within the first 3 weeks (r = 0.32, $P = 0.05$). Workload constitutes a major stressor in stressor in dairy farming (Kallioniemi et al., 2016). By sharing the work or having an extra work force, additional workers in calf husbandry might enable farms to share the total workload and thus to implement more recommendations. Vaarst and Sørensen (2009) interviewed farmers that reported having “extra time” allocated to disease problems as an integral part of successful calf management. They also found that farmers who increased the number of cows were overwhelmed by the additional calves, which demanded more individual attention than adult animals. In our interviews, 4 of the 6 farms that raised bull calves and 2 farms that expanded recently also mentioned they lack capabilities to implement management recommendations due to the high number of calves. Five of these farms had implementation rates of below 50%.

**Table 2.7.** Spearman rank correlations between the rate of implementation of recommendations with stockperson characteristics, farm characteristics and the stockpersons attitude toward animal welfare.

| Variables | Implementation rate of recommendations, % | | | | | |
|---|---|---|---|---|---|---|
| | Total rate | Calving management | Colostrum management | Housing and transport | Calf feeding | Painful procedures |
| Stockperson's characteristics | | | | | | |
| Sex (male, female) | NS | NS | NS | NS | NS | NS |
| Age (in years) | NS | NS | NS | NS | 0.45** | NS |
| Education (no agricultural education, …, university degree in agriculture)[1] | NS | -0.29† | 0.48** | NS | NS | NS |
| Animal welfare training (no, yes) | NS | NS | NS | NS | NS | NS |
| Farm characteristics | | | | | | |
| Herd size (number of dairy cows) | NS | NS | NS | NS | NS | -0.38* |
| Consultation of veterinarian (no, yes) | NS | 0.35* | NS | NS | NS | NS |
| Treatment by veterinarian (no, yes) | 0.28† | NS | 0.33* | NS | NS | NS |
| Number of responsible stockpersons | 0.28† | NS | NS | NS | NS | 0.45** |
| Farmer responsible (no, yes) | NS | NS | NS | NS | NS | NS |
| Spouse responsible (no, yes) | NS | NS | 0.27† | NS | NS | NS |
| Worker responsible (no, yes) | 0.53** | NS | NS | 0.31* | 0.35* | 0.39* |
| Children responsible (no, yes) | NS | NS | NS | -0.43** | NS | NS |
| Attitude toward animal welfare | | | | | | |
| Importance of animal welfare[2] | 0.31* | NS | NS | NS | NS | 0.30† |
| Development depending on animal welfare[2] | NS | NS | -0.34* | NS | NS | NS |
| Animal welfare self-assessment[3] | NS | NS | NS | NS | NS | NS |

[1]Detailed education levels can be found in detail in Table 2.1.

[2]Numerical scale: 1 = not important at all, 10 = extremely important.

[3]Numerical scale: 1 = extremely low farm animal welfare level, 10 = extremely high farm animal welfare level.

†0.05 < *P* < 0.1; **P* < 0.05; ***P* < 0.01.

### 2.4.9. Respondents Views on Animal Welfare

“Problem awareness and perceived responsibility” and “farmers characteristics” are 2 of 5 reasons behind management decision making identified by Ritter et al. (2017), which could also affect relevant animal welfare management decisions in dairy calves. In total, most respondents stated that animal well-being is especially important for them personally, but also for the development of the calf (median 9.0 and 9.4 respectively, on a numerical scale of 1–10). The personal importance of animal welfare correlated positively with the number of management recommendations implemented (Table 2.7), confirming the hypothesis that the personal beliefs of the stockpersons constituted a major driver for implementation of the recommended management. However, the self-assessment of the respondents regarding the well-being of their calves (median 7.6 on a numerical scale of 1–10) was not reflected in the degree of implementation of management recommendations (Table 2.7). This difference might be caused by the missing ability of the stockperson to reflect their status, and thus over- or underestimating their management.

The most frequent aspects that respondents stated to be important for calf wellbeing are shown in Figure 2.4. Even though, most stockpersons highly valued access to feed and water and the absence of pain as important for calves’ welfare, correlations between stockpersons mentioning these factors and the implementation rate in the management of painful procedures and feeding were absent. Missing knowledge might be an explanation for this discrepancy. We recognized in our interviews that some farmers believed that sedation was sufficient for complete pain relief. This is supported by surveys on disbudding, in which over 40% of farmers stated that disbudding only causes moderate pain (Gottardo et al., 2011; Staněk et al., 2018). Interestingly, the number of animal-related aspects (e.g., “feeling no pain,” “expression of joy full behavior,” “being healthy”) was positively related to the implementation rate of management recommendations ($r = 0.33$; $P = 0.04$). Although the number of stated resource-related aspects (e.g., “enough space,” “sufficient bedding,” “access to feed and water”) tended to be negatively correlated to the total implementation rate ($r = -0.3$; $P = 0.06$), indicating that stockpersons, who were able to assess the needs of calves from the animal’s perspective, consciously or unconsciously implemented more management recommendations. The ability of stockpersons to empathize with calves’ emotions led to better handling and higher productivity (Lensink et al., 2000). Fostering this relationship could be an approach to improve calf management. However, for on-farm assessments of calves’ well-being, predominantly animal-related indicators were stated (Figure 2.4).


**Figure 2.4.** Word clouds generated using the categorized answers of 42 stockpersons surveyed to questions on their attitude toward animal welfare. The word clouds included only answers that were given by at least 5 respondents; the size of the words is relative to the frequency of mention.

Two of the 42 respondents could not or did not want to indicate how they could increase the animal welfare of their calves. Investments in husbandry systems and techniques were the predominant strategy used by the respondents to increase animal welfare in the future, with 67.5% of the respondents suggesting this approach. Those technical changes included the purchase of more boxes or hutches, the replacement of existing hutches with more space, giving access to an outlet, covering an already existing outlet with a roof, or implementing a ventilation system in the calf housing. These aspects align with the aspects seen as important for the welfare of calves (Figure 2.4). One reason for this focus on technical properties might be that German animal welfare subsidies are connected to changes in housing systems, such as new barns (Bergschmidt and Schrader, 2009). Nevertheless, this and other studies identify considerable potential to improve animal welfare by improving farm management with changes that are only indirectly connected to husbandry systems and techniques such as the sufficient provision of colostrum, proper hygienic measures, or the use of pain mitigation measures for painful procedures (Shivley et al., 2018; Staněk et al., 2018; Heinemann et al., 2020). Many of these management measures are highly time-intensive. Improving the feeding management was mentioned by 22.5% and improving feeding techniques by 14.3% which was specified as providing water and solid feed earlier in single housings, and feeding more milk or only whole milk instead of other milk equivalents. Additionally, improving the hygiene management and lowering the disease incidence was stated by 12.5% and 10% of the respondents, respectively.

These answers indicate that some respondents were aware of current recommendations but were still hindered in implementing them due to other reasons than missing knowledge. Most interesting is that 22.5% of the respondents stated that a change or an improvement in their working routine could lead to an improvement in animal welfare, which supports the prior mentioned hypothesis that not implementing certain management recommendations might be caused by a lack of time and work force.

Regarding investments in the past 6 mo leading up to the farm visit, 42.9% of the respondents stated that they had invested monetarily in the welfare of their calves, and only 28.6% stated that they wanted to invest in the next 6 mo. Many of those investments mentioned were investments into new hutches or boxes (Supplemental Table S7.2). None of the farmers mentioned any nonmonetary investment, even though this question was addressed at the end of our interview.

### 2.4.10. Limitations

Limitations of the study were associated with the criteria for farm selection and the resulting limited number of farms including their regional distribution. Using an already established relationship between the farms and us as investigators resulted in a trade-off between data quality and representativity. In general, participants of surveys are biased by their willingness to participate. In addition to the time investment in the interview, participating farmers agreed to discuss critical aspects of production and authorized unhindered access to their facility. Considering this, response rate and the number of farms (n = 42) were comparably high. Evaluating the stockpersons' responses to critical aspects such as admitting noncompliance with recommendations or legal requirements and their reports of high disease incidences and mortalities indicated that responses seemed to be honest. Nevertheless, disease incidences and mortalities based on farmers self-reports are shown to be biased (Svensson et al., 2003). Despite the described biases, the identified challenges in calf management are likely transferable to western German dairy farms in general because the prior studies, in which the farms participated, were designed to reflect typical western German dairy farms management.

## 2.5. Conclusions

The results of this study provided novel insights on dairy calf management on western German dairy farms. Several recommendations were widely implemented (e.g., use of calving pens or teat buckets) but also potential areas for improvement (e.g., hygiene management or total pain mitigation for painful procedures) were identified. Reasons for implementing management recommendations were seen in the availability of workforce for calf rearing and in the beliefs of the stockperson in the importance of animal welfare. Identified challenges seemed to be limitations of used individual housing systems, time management, stockperson knowledge, or their ability to relate to the animals, which should be investigated in future research.

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# 3. Wound lesions caused by ear tagging in unweaned calves: Assessing the prevalence of wound lesions and identifying risk factors

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## 3.1. Abstract

Identification of cattle by ear tagging is legally required to ensure traceability. However, studies indicate that ear tagging causes pain-associated physiological and behavioral responses. The wound healing process and prevalence of wound lesions in calves remain mostly unknown. Therefore, this study sought to estimate the prevalence of wound lesions and identify associated risk factors by assessing ear tagging management in unweaned dairy calves. We conducted one field study with single visits to estimate the prevalence of wound lesions and associated risk factors (**Study 1**, 42 farms, 802 calves) and one follow-up study with repeated visits to assess farmers' view on ear tag management, the relationship between calf health and wound healing, and the development of wound lesions over time (**Study 2**, 5 farms, 42 calves). Study 1 comprised a short interview with the farmer (four questions regarding ear tagging). Ear tag position (on or between ridges) and wound lesions were evaluated using a three-level scoring system (1 = no blood, scab, or pus discharge; 2 = incrustation or scab and slight blood or pus discharge; and 3 = heavy purulent discharge, tissue deformation, or both). In Study 2, farmers were interviewed about ear tagging (30 questions), and 10 calves from each farm were assessed on the day of ear tagging and 1, 3, and 6 weeks after tag insertion. Calf health, ear tag position, and wound characteristics were assessed during all visits. Both studies were analyzed descriptively, and odds ratios (**ORs**) for wound lesions in Study 1 were calculated using logistic regression. Of the ears assessed in Study 1, 31.1% showed clinical signs classified as category 2. Score 3 was less common and was found for 6.7% of all ears. Although the highest incidence of wound lesions was found in calves aged 2–4 weeks, wound lesions were also found in calves aged > 10 weeks (18.5%). Identified risk factors for wound lesions were small farm size, calf age, single housing, group size, placement of ear tags on ridges, and other ear's score. Individual farmers in Study 2 were able to place ear tags very accurately, although awareness about ear tag lesions appeared to be low among farmers. Sensitizing farmers to this issue, implementing routine checkups of ear tag wounds 2 weeks after insertion, and considering the identified risk factors may reduce animal welfare impairments associated with ear tagging.

***Keywords:*** identification, painful procedure, animal welfare, auricle, inflammation

## 3.2. Implications

In the EU, identification by ear tagging is the only painful procedure legally required on calves, and it must be performed in the first weeks of life. In two field studies on wound lesions in unweaned calves on dairy farms, insertion management and possible risk factors were evaluated. More than a third of all calves showed signs of wound lesions, which were associated with farm size, group size, calf age, and tag position. The identified risk factors and resulting recommendations may be useful for future research and practical management aimed at improving animal welfare.

## 3.3. Introduction

As a response to the bovine spongiform encephalopathy crisis in 1997, the Council of the European Union implemented a unionwide identification and traceability system for bovine animals (Ammendrup and Füssel, 2001; European Commission, 2021). The primary objectives of this identification and traceability system are the localization and tracing of cattle to control infectious diseases, traceability for public health reasons, particularly food safety, and support for the management and organization of international livestock trade (European Commission, 2021). According to current regulation (EC) No. 1760/2000 of the European Parliament and of the Council of 17 July, 2000, each bovine animal must be identifiable by ear tags (conventional ear tags or electronic identifiers) on both ears bearing a unique identification code or since 2019, by electronic identifiers (electronic ear tag, ruminal bolus, injectable transponder) accompanied by a passport. The time by which the cattle must be identifiable is determined by each member state; however, it should not exceed 20 days after birth. The design and other requirements of ear tags are specified in EC No. 911/2004 of 29 April, 2004, including the requirement that ear tags should be designed in such a way that they can remain attached to the animal without being harmful to it. The EU regulations have been incorporated into German law (BMJV, 2007), which further prescribes that ear tags must be inserted by the keepers within 7 days after the birth of the animal.

Furthermore, European legislation states that member states shall make provisions to ensure that farm animals are not caused any unnecessary pain, suffering, or injury (EU CD 98/58/EC). The German Animal Welfare Act (BMJV, 2006) forbids performing painful procedures without anesthesia. Although ear tagging is listed as an exception to this regulation, measures to minimize pain must be applied (BMJV, 2006). Even though it is legally required and performed on every calf born in the EU, studies on the adverse effects of ear tagging are relatively rare.

Nevertheless, studies with varying experimental settings showed that ear tag insertion was associated with an increase in pain-related behaviors such as head shaking, ear scratching, tail wagging, foot-stamping, and vocalization (Lomax et al., 2017; Turner et al., 2020, Schnaider et al., 2022). Stewart et al. (2013) evaluated the effect of routine husbandry procedures (ear tagging and disbudding) and found that ear tagging led to increased heart rates and more tail flicking. However, in comparison to disbudding, fewer behavioral and physiological responses were recorded in their study.

In addition to the pain caused by the procedure itself, animals also suffer from ear damage due to ear tag losses and wound lesions. Long-term animal welfare impairments due to wound inflammation have been reported by Wendl et al. (2011) for sheep, with 27.2% and 88% of sheep showing signs of inflammation and incrustation, respectively, 4 weeks after insertion, respectively. Till date, data on wound healing in calves are limited. Salina et al. (2016) reported the cases of severe ear necrosis in adult ear-tagged cattle in a study conducted in Malaysia. Johnston and Edwards (1996) evaluated changes observed in calves 4 weeks after ear tag insertion (metal and plastic ear tags) and found a higher prevalence of ear damage due to metal (47.3%) than plastic (1.1%) tags. However, to our knowledge, no recent study has estimated the prevalence of lesions after ear tagging on farms.

To minimize pain due to ear tagging and improve wound healing, studies recommend the placement of ear tags centrally between the two main ridges of the ear auricle as they are relatively free of larger blood vessels, nerves, hair, and sebaceous glands (Rashid et al., 1987; Wendl et al., 2011). Wendl et al. (2011) identified age at ear tagging, breed, farm effects, and ear tag position as influential factors in wound healing in ear-tagged sheep. However, most identified risk factors have not been confirmed in unweaned calves, and the management of ear tagging calves on farms and its effects on ear-tagged calves remain mostly unknown.

Wound healing in general can be delayed by systematic factors such as animals' condition and health or by local factors like wound infections or skin motion (Bertone 1989). Especially, newborn calves are prone to infections as their immune system is not fully developed and dependent on colostrum intake (Weaver et al., 2000; Godden et al., 2019) and hygienic conditions on farm are often insufficient (Heinemann et al., 2021; Hayer et al., 2021a), increasing the theoretical likelihood of delayed healing of ear tag wounds.

In this study, the results from two studies are reported. These studies aimed to 1) determine the prevalence of wound lesions due to ear tagging in unweaned calves and identify possible risk factors in a field study and also to 2) assess farmers' view on ear tag management, the development of wound lesions over time, and the relationship between wound healing, calf health, and hygienic conditions.

## 3.4. Material and methods

The results are based on one broad, one-visit field study conducted among 42 Western German dairy farms (Study 1, 802 unweaned calves) and one controlled trial with five dairy farms located in Western Germany (Study 2, 48 unweaned calves, with 9–10 calves per farm); the farms were visited on the day of ear tagging and 2, 3, and 6 weeks after ear tagging.

### 3.4.1. One-time assessment in the field

Study 1 aimed to assess the prevalence of wound lesions in tagged ears in unweaned dairy calves and determine the effect of possible risk factors such as calf characteristics and management. A total of 802 unweaned dairy calves on 42 Western German dairy farms, located in Rhineland-Palatinate and North Rhine-Westphalia, were visited once during November 2018 to April 2019 and October to December 2019. Farm selection and visit procedures were described in detail in previous publications focusing on dairy calf management and influences on welfare indicators in general (Hayer et al., 2021a, b). In summary, farms that have participated in previous studies were contacted and asked for participation. Farms were visited by one of two trained investigators, known to the farmers, who interviewed the person responsible for calf rearing upon arrival and assessed the husbandry system as well as unweaned calves on the farm using an assessment protocol comprising 21 resource- and animal-based indicators. The two observers trained the assessment protocol in a pre-study with two farms and 60 calves to assure a common understanding. The interview guidelines included four questions regarding ear tagging: 1) When do you insert ear tags?; 2) Who is responsible for ear tagging?; 3) Is the person responsible for ear tagging right- or left-handed?; and 4) Are ears of ear tagged calves inspected for signs of inflammation? Because the first question was an open question, answers were categorized based on the ear tagging routine (insertion directly after birth, on a specific day, at a specific age) and maximum time spent until insertion (< 24, 24–72, and > 72 hours postpartum).

Calf age, calf sex, housing form (single or group housing), and animal number per group were recorded for each unweaned calf on the farm. European and German national regulation requires calves to be ear-tagged on both ears with one ear tag per ear within the first 7 days postpartum. Therefore, both ears of all ear tagged calves were evaluated for the position of the ear tag (on or between ridges, Figures 3.1A and 1B) and wound lesions using a three-level scoring system, which was defined as follows: 1 = no blood, scab, or pus discharge (Figures 3.1A and 1B), 2 = incrustation or scab, slight blood or pus discharge (Figure 3.1C), and 3 = heavy purulent discharge, tissue deformation, or both (Figures 3.1D, 3.1E, and 3.1F). Tissue deformation included: incisions of ear tag flags into the lower or upper ear ridges (Figure 3.1D), squeezed ear ridge tissue (Figure 3.1E), ear tags that were too tight and starting to be pulled through the ear tissue, and tagging through the auricle twice by additional pinning of the upper ear arc (Figure 3.1F).

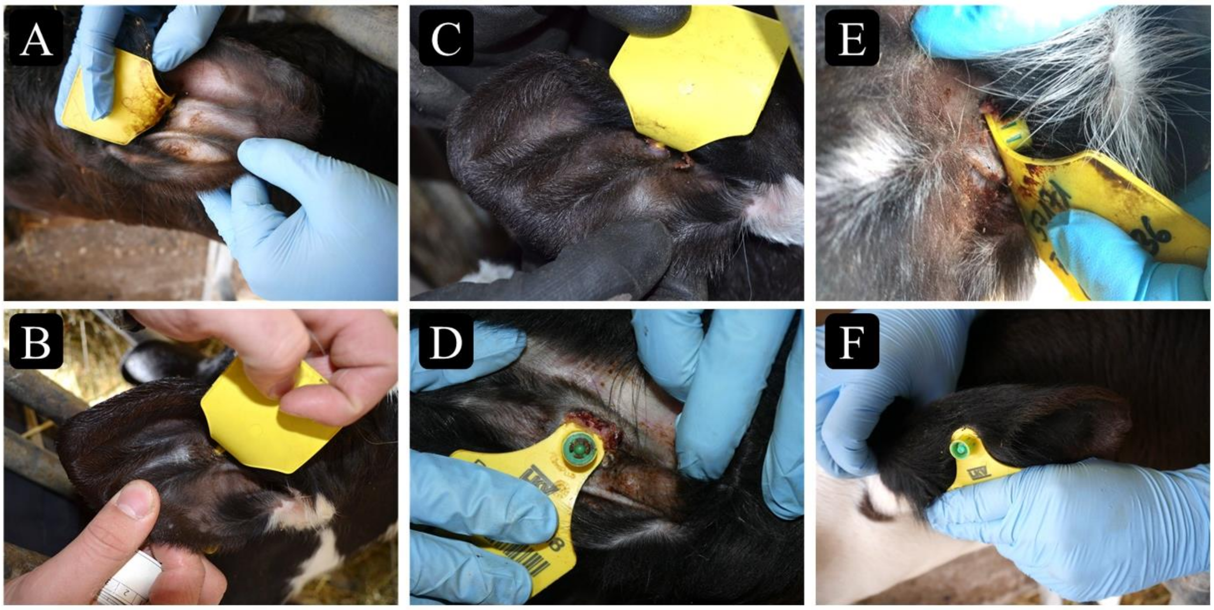



**Figure 3.1.** Ears of unweaned ear-tagged calves in Study 1, which were evaluated regarding ear tag position: on ear auricle ridge (A, D) or between ear auricle ridges (B, C, E, and F), and ear tag lesions based on a three-level scoring system: 1 = no blood, scab, or pus discharge (A and B), 2 = incrustation, slight pus or blood discharge (C), and 3 = heavy purulent discharge, tissue deformation, or both (D, E, and F). Observer wore black, blue, or no glove during the assessment.

*Statistical analysis*

The descriptive results were described as the percentages of the wound healing score or farms for qualitative data, whereas quantitative data were described as means with standard deviations using the FREQ and MEANS procedures of SAS (version 9.4, SAS Institute Inc., Cary, USA). Logistic regressions were calculated with multivariable linear models to analyze possible risk factors for scores 2 or 3 of the wound healing scoring. Based on missing differences between ear sites, data of all ears were combined for further analysis. Risk factors were “herd size,” “number of animals per pen,” “single vs. group housing,” “calf sex,” “calf age,” “ear site,” “observer,” “ear tag position,” “scoring on the other ear,” “insertion time,” “insertion routine,” “person responsible for ear tagging,” and “favored hand of tagging person.” The variable “observer” was included to take differences between observers into considerations. However, both observers did not assess calves simultaneously, making it impossible to distinguish between observer and farm effects. Two binary logistic regression were conducted for scoring levels 2 and 3, respectively, for all ear evaluations combined using the “glm” function of the “MASS” package of R (R Core Team, 2013) based on Rawat (2017). The Akaike Information Criteria of our initial model was calculated and optimized by applying the “stepAIC” function with both forward and backward selection to remove multicollinearity and optimize the set of explanatory predictors. The final models include the explanatory variables “observer,” “herd size,” “number of animals per pen,” “single vs. group housing,” “calf age,” “ear tag position,” and “scoring on the other ear.” Calculated logistic odds ratios (**ORs**) and confidence intervals were exponentiated to obtain ORs and confidence intervals. ORs were considered significant at $P < 0.05$, with $P < 0.01$ indicating highly significant ORs and $0.05 < P < 0.1$ indicating a statistical tendency.

### 3.4.2. Repeated assessment over time on five selected farms

Study 2 aimed to assess farmers’ view on ear tagging management on dairy farms as well as ear tag wound development over 6 weeks and their association with calf health. Farms were visited from the beginning of February 2020 to the end of April 2020. As in the previous study (Hayer et al., 2021a), only farms with an established relationship with the visiting researcher were included to increase the likelihood of honest answers and decrease the possibility that farmers might change their calf management due to the study. After an initial phone call explaining the study’s objective, the same trained investigator visited the selected farms multiple times. Initially, the study was intended to include 10 farms based on feasibility and funding. However, due to the outbreak of the COVID-19 pandemic and the restrictions imposed at the end of April 2020, the remaining farm visits had to be canceled, and only five farms were finally included.

*Interview regarding ear tagging*

During the first farm visit, a questionnaire comprising 30 questions was completed based on the responses of the person responsible for ear tagging. The options to answer the questions were qualitatively nominal (e.g., yes or no), continuous (e.g., number of calves tagged per year), free-text statement (e.g., description of the calf handling during ear tag insertion), and graphical (crossing the aimed ear tag position for the left and right ears on a full-scale ear map). The interview guidelines focused on calves of both sexes. However, they included two questions directed at differences between male and female calves (differences in insertion process and differences between tag manufacturers used). Following the interview during the first visit, calf facilities were visually assessed by the investigator. The farm agreed to inform the investigator about the time of ear tagging in case of a newborn calf.

*Calf assessment*

The first 10 calves born in the weeks following the first visit to each farm were included in this study. Each calf was assessed four times: at the date of ear tagging and 1, 3, and 6 weeks after ear tag insertion. The assessment dates were based on a primary analysis of study 1, showing that most signs of wound lesions due to ear tagging were most prevalent in this period. Male calves were sold as soon as they were 14 days old on all farms, and three calves died during the study, resulting in fewer observations for week 3 and 6. An extension of the study period was not possible due to restrictions caused by the COVID-19 pandemic in 2020. Ear tagging and individual calf assessments were performed 2–4 hours after feeding to minimize stress and possible negative effects on milk consumption. At the beginning of each assessment, the condition of calves’ bedding was evaluated using a four-level scoring system (0 = clean, dry; 1 = slightly dirty, slightly damp; 2 = dirty, wet; 3 = extremely dirty, extremely wet) based on the study by Barry et al. (2019). Calf health was evaluated using the calf health scoring system from the School of Veterinary Medicine of the University of Wisconsin-Madison (https://fyi.extension.wisc.edu/heifermgmt/files/2015/02/calf_health_scoring_chart.pdf), which included rectal temperature; coughing; nasal discharge; eye; ear; and fecal scores. A total respiratory disease score was calculated by combining coughing, nasal discharge, eye, and ear scores. Calves were diagnosed with pneumonia when the respiratory disease score was greater 4 and with diarrhea when the fecal score was greater than 1. In addition, respiration rate and girth height were measured. Ear tag wounds were evaluated using a more detailed assessment than that used in Study 1, which was different in the following factors: 1) head position (0 = neutral head posture; 1 = oblique head posture), 2) resistance during inspection (0 = no or only slight attempts to pull the head away during ear inspection; 1 = strong attempts to pull the head away during ear inspection), 3) drooping ear (0 = normal; 1 = ear droop), 4) tissue deformation (0 = no tissue deformation; 1 = tissue deformation), 5) incrustation (0 = normal; 1 = visible crustation), 6) pus discharge (0 = no discharge; 1 = pus discharge), 7) heated tissue (0 = normal feeling when touched; 1 = heated tissue when touched), 8) swelling (0 = no swelling; 1 = swelling around the ear tag); 9) reddening (0 = normal tissue color; 1 = reddened tissue), and 10) bleeding (0 = no blood discharge; 1 = blood discharge around ear tag). During each assessment, the ear tag position was assessed using the same blank full-scale ear maps used in the interviews with farmers. The assessment was performed in the calf pens and tested in a pre-study on another farm and discussed with the researchers of Study 1.

*Statistical analysis*

Descriptive statistics were performed as described in Study 1. Spearman's rank correlations were determined via the CORR procedure of SAS to evaluate the correlation among age, animal health records (single and combined scores), and ear tag related wound healing signs. The NPAR1WAY procedure of SAS with the WILCOXON statement was used to determine differences between the four assessments (day of ear tagging, 1, 3, and 6 weeks after ear tagging) by Wilcoxon signed-rank tests as the outcome variables were mostly categorial and dependent variables. As in Study 1, correlations and differences were considered significant at $P < 0.05$, with $0.05 < P < 0.1$ indicating a statistical tendency.

## 3.5. Results

### 3.5.1. Results of the one-time assessment in the field

*Descriptive results of farmer survey and calf ear assessment*

**Table 3.1.** Reported herd size and ear tagging management on Western German dairy farms (n = 42) in Study 1.

| Variable | Category | n (%) |
|---|---|---|
| Herd size (n = 42) | < 100 cows | 11 (26.2) |
| | 101–200 cows | 23 (54.8) |
| | > 200 cows | 8 (19.1) |
| Person responsible for ear tag insertion (n = 42)[1] | Farmer | 29 (62.5) |
| | Children | 2 ( 4.8) |
| | Both, farmer and children | 5 (11.9) |
| | Spouse | 2 ( 4.8) |
| | Worker | 4 ( 9.5) |
| Preferred hand of ear tagging person (n = 42) | Right-handed | 39 (92.9) |
| | Left-handed | 1 ( 2.4) |
| | Both | 2 ( 4.8) |
| Ear tagging routine (n = 42)[1] | Directly after birth | 18 (42.9) |
| | Fixed day in the week | 10 (23.8) |
| | At a specific age | 24 (57.1) |
| Calf age at ear tagging (n = 42) | < 24 h p.p. | 18 (42.9) |
| | 24–72 h p.p. | 8 (19.1) |
| | 72–168 h p.p. | 14 (33.3) |
| | > 7 d p.p. | 2 ( 4.8) |
| Inspection of ear tag wounds (n = 42) | Yes | 9 (21.4) |
| | No | 33 (78.6) |

[1]Multiple answers possible

Detailed descriptions of the participating farms and stockpersons' characteristics are presented in Hayer et al. (2021a); therefore, only additional information on ear tag insertion management is shown in this study (Table 3.1).

In total, 844 unweaned calves were assessed on the farms visited, of which 802 were already ear-tagged and included in this study. More female calves (81%) were maintained on the dairy farms than male calves (19%). The median age of calves assessed was 43 days, with a minimum age of 1 day and a maximum age of 128 days. Ear tags were placed on one of the two main ridges of the ear auricle in 39.8% of all ears evaluated. Crusting, scabbing, or pus or blood discharge (score 2) was found in 31.1% of all ears. However, heavy discharge or ear tissue deformation (score 3) was recorded only in a small number of calves (6.6%). Figure 3.2 illustrates the distribution of ear tag scores in relation to calf age. The highest prevalence for score 2 was found in the first two to four weeks of age for both ears (55.2%). With increasing age, the prevalence of scores 2 and 3 decreased after the first 4 weeks. For calves aged > 10 weeks, the prevalence of score 2 was 19.6%, whereas that of score 3 was 3.8%. In addition to the assessment based on the three scoring levels, some ear tag wounds showed more specific pathological changes, such as changes resulting from mechanical friction (Figure 3.1E) or ear arches that were tagged together (Figure 3.1F).

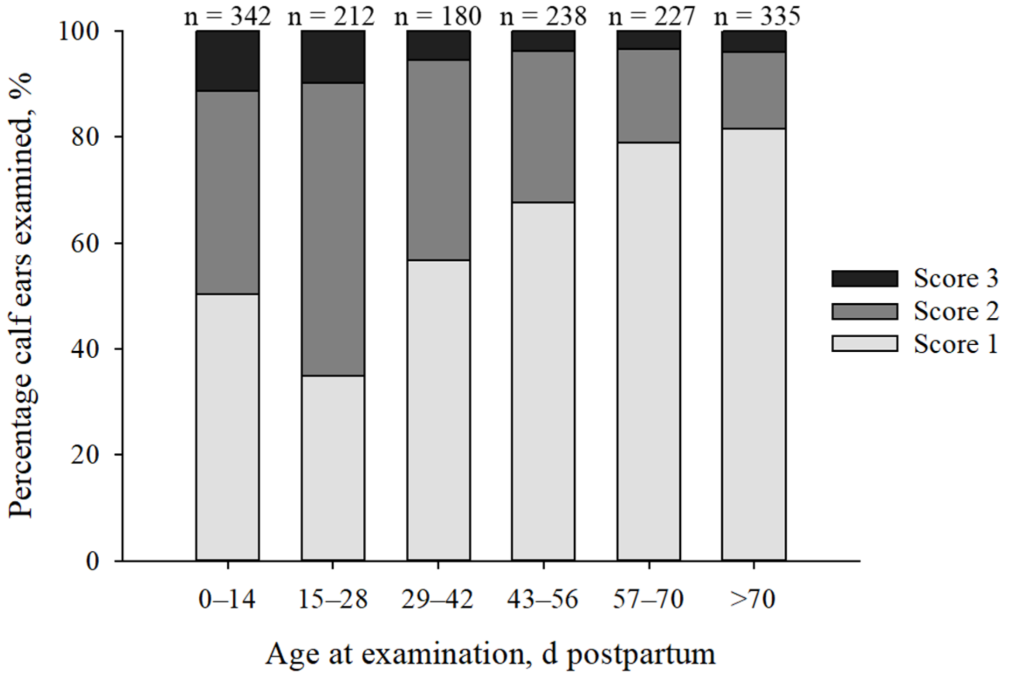



**Figure 3.2.** Prevalence of wound lesion scores (1 = no blood, scab, or pus discharge, 2 = incrustation or scab, slight pus or blood discharge, 3 = heavy purulent discharge, tissue deformation, or both) in the ears of 802 unweaned dairy calves on 42 Western German dairy farms in Study 1 according to age.

*Risk factors for wound lesions caused by ear tagging*

To identify the possible risk factors for the occurrence of mild (score 2) and severe (score 3) wound lesions, ORs were calculated for different possible factors for all ears combined (Figure 3.3; Supplementary Tables S7.3 and S7.4). Calves held on large (> 200 cows), and medium-sized (100–200 cows) farms had significantly lower odds of having a score of 2 compared with calves held on small (< 100 cows) farms (OR: 0.60 and 0.73, respectively). The odds of scores 2 and 3 were significantly lower for calves aged > 6 weeks than for calves aged 1–2 weeks (OR: 0.61 and 0.31, respectively). The placement of ear tags on the ridges of the auricle highly significantly increased the risk of score 2 (OR: 1.51). The outcome of the assessment of one ear had a large impact on the other ear's scoring. A score of 2 on one ear highly significantly increased the odds of the other ear being scored with a 2 by a factor of 3.02. This effect was even larger for score 3, for which the odds highly significantly increased by a factor of 4.67 if the other ear was also scored with a 3. Neither the sex of the calf, the stated inspection of wound healing processes by respondents, the ear site, nor the preferred hand of the person inserting ear tags significantly affected the risk of mild or severe wound lesions and therefore were not included in the model.

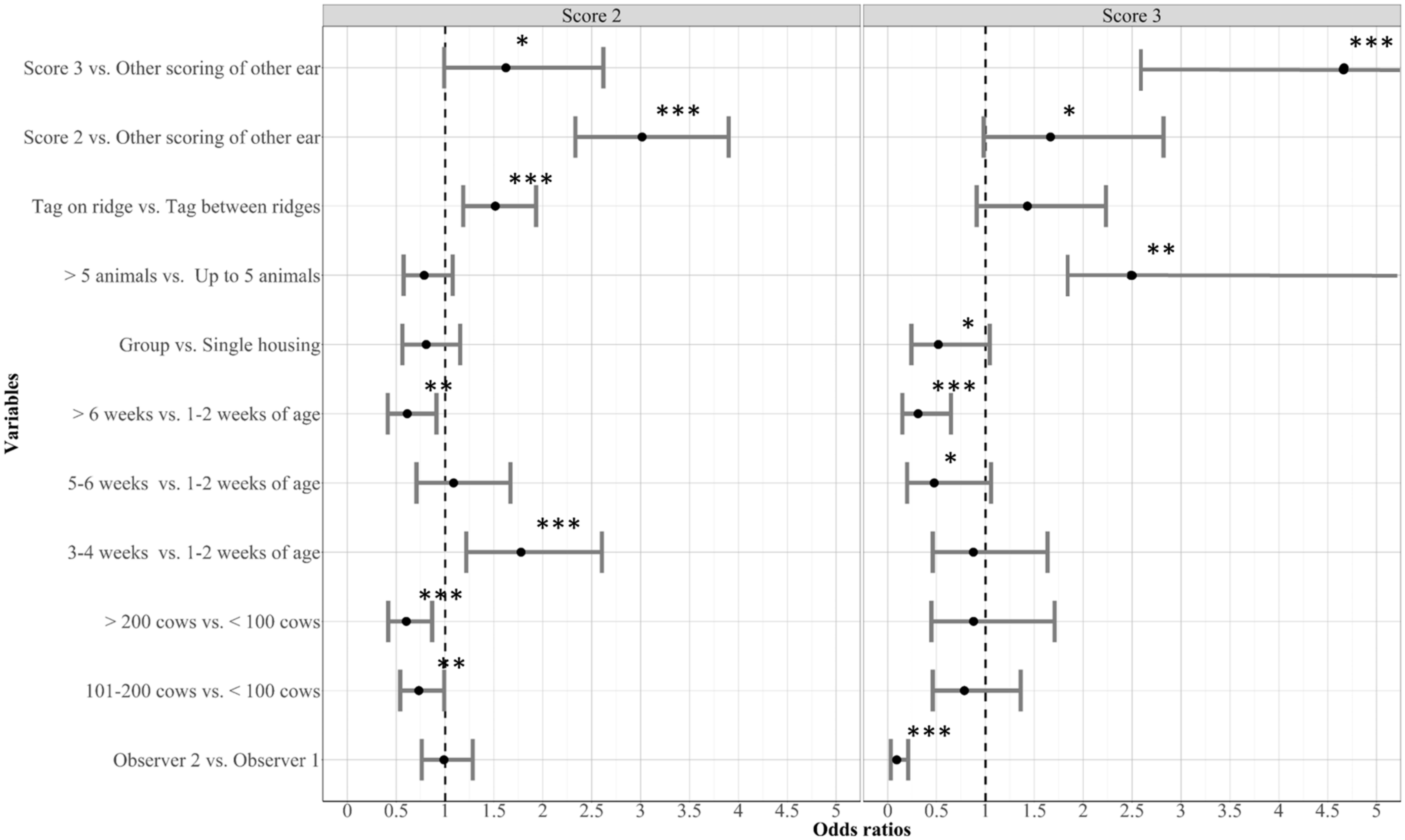



**Figure 3.3.** Calculated odds ratios for different farms and calf characteristics, ear tag management decisions, and ear scorings based on the results of ear tag lesion scores in Study 1 (2 = incrustation or scab, slight pus or blood discharge, 3 = heavy purulent discharge, tissue deformation, or both), with * indicating *P* < 0.05, ** indicating *P* < 0.01, and *** indicating *P* < 0.001. Dots mark the estimated odds ratios and the whiskers end at the lower and upper end of the 95% confidence interval. Detailed odds ratios and confidence intervals are assessable in the Supplementary Tables S7.3 and S7.4.

### 3.5.2. Results of the repeated assessment over time on five selected farms

*Descriptive results of farmer survey and calf assessments*

Characteristics of the participating farms and respondents are presented in Tables 3.2 and 3.3. Three of the five farms differentiated between male and female calves in ear tagging. Farms 2 and 3 ear tagged bull calves earlier to register and sell them at the earliest (at least 14 days of age).

**Table 3.2.** Reported farm and interviewee characteristics on five Western German dairy farms in Study 2.

| | Person interviewed | | | | Farm characteristics | | |
|---|---|---|---|---|---|---|---|
| Farm | Age, years | Sex | Educational degree | Position | Herd size, cows | Calves tagged per year | Experience in ear tagging, years |
| 1 | 38 | Male | Agricultural college | Farmer | 110 | 100 | 20 |
| 2 | 43 | Male | Agricultural master craftsmen | Farmer | 92 | 115 | 22 |
| 3 | 25 | Male | Agricultural college | Farmer | 147 | 95 | 8 |
| 4 | 56 | Male | Agricultural college | Farmer | 150 | 175 | 40 |
| 5 | 25 | Male | University degree in agriculture | Farmer | 223 | 150 | 10 |

Farm 2 also used different ear tag manufacturers depending on sex (Allflex for male calves; Caisley for female calves). On all farms the ear tags were inserted by only one person; four farms inserted the ear tags with the calves in the standing position and two while holding them between a person’s legs.

**Table 3.3.** Reported ear tagging management on five Western German dairy farms in Study 2.

| Farm | Differences in calf sex | Time of insertion | Tag manufacturer | Ear tagging process |
|---|---|---|---|---|
| 1 | None | 24–48 h p.p. | Caisley | Lying calf, one person, no fixation |
| 2 | Time of insertion, tag fabricant | After 7 d p.p. | Caisley, Allflex | Standing calf, one person, no fixation |
| 3 | Time of insertion | 24–48 h p.p. | Allflex | Standing calf, one person, fixation between legs |
| 4 | None | Directly after birth | Allflex | Standing calf, one person, no fixation |
| 5 | None | Directly after birth | Allflex | Standing calf, one person, fixation between legs |

Figure 3.4 shows the combined results of the interviewee responses regarding the aimed ear tag position on the full-scale ear map and the assessment of ear tag positions. Farms differed in the aimed position of ear tags; farms 3 and 5 placed the ear tags close to the base of the ear, farms 2 and 4 between the middle of the ear and the ear base, and farm 1 at the middle of the ear. All farms aimed to place the tag between the two ear ridges. By comparing the aimed ear tag position and placed ear tags of the calves assessed, it was noted that farms 3 and 5 managed to place all ear tags relatively close to their stated target. Farms 2 and 4 placed most ear tags near the aimed position but had some deviations, and farm 1 placed only a few ear tags near the aimed position.

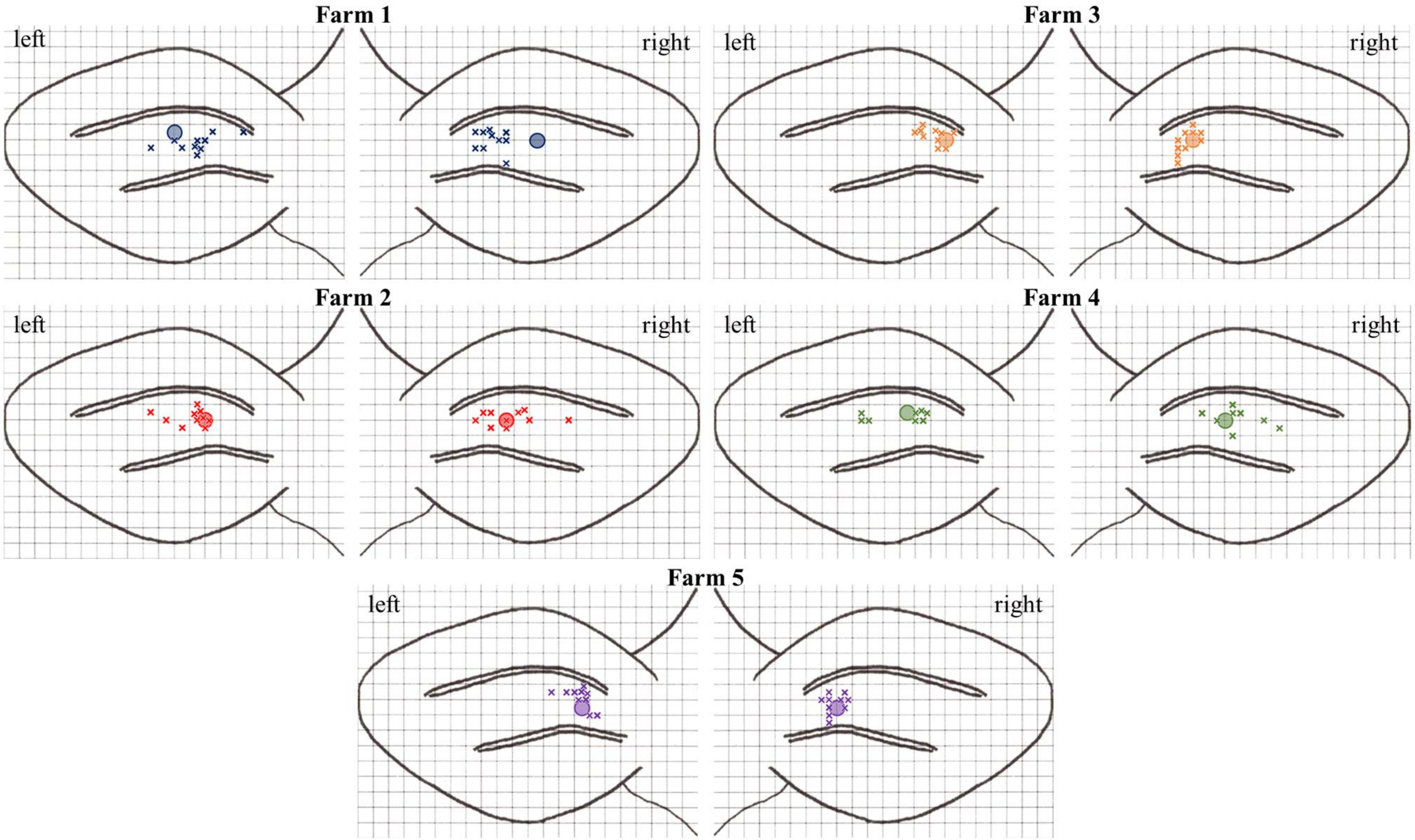
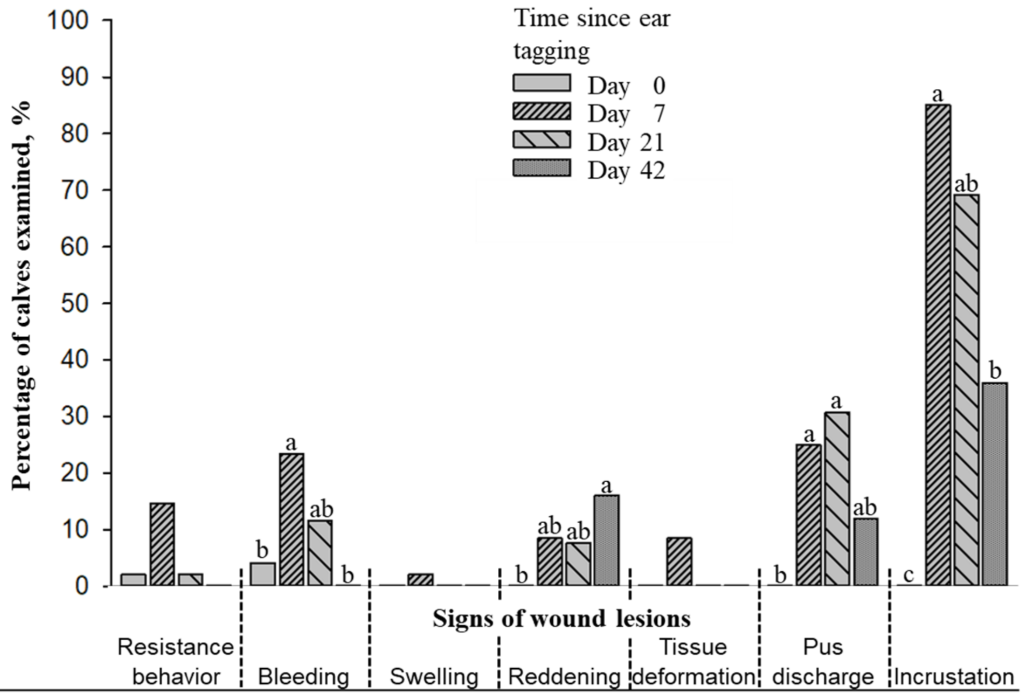



**Figure 3.4.** Evaluation of aimed ear tag position (colored circle) of five interviewed farmers and the ear tag position of 9–10 calves per farm (crosses) for the left and right ears in Study 2.

*Wound lesions and calf health*

All farmers stated that wound lesions such as swelling, incrustation, tissue deformation, and pus discharge due to ear tagging were rare or nonexistent on their farm (Figure 3.5). However, the assessments of the calves revealed that incrustations were visible in 36.7%–53.8% of all assessments. On the other hand, bleeding was reported by all respondents but occurred less frequently than incrustation or tissue deformation. Regarding the time of observation, incrustations were found more frequently after 7 and 21 days (85.1% and 69.2%, respectively) than directly after insertion (0%, $P < 0.001$) or after 42 days (36.0%, $P = 0.09$). Furthermore, bleeding was found more frequently after 7 days than directly after insertion or after 21 days ($P = 0.05$). However, the highest prevalence of pus discharge was observed during the visit after 21 days (30.8%), which was significantly higher than that at day 0 ($P < 0.001$), at which point no incidence was recorded. Other signs were only rarely observed (< 25%), and no statistical difference between assessments was found.




| Estimations of farmers, % | Resistance behavior | Bleeding | Swelling | Reddening | Tissue deformation | Pus discharge | Incrustation |
|---|---|---|---|---|---|---|---|
| Farm 1 | 0.0 | 5.0 | 1.0 | 0.0 | 0.0 | 0.0 | 2.0 |
| Farm 2 | 0.0 | 10.0 | 0.0 | 0.0 | 0.0 | 1.0 | 5.0 |
| Farm 3 | 6.0 | 4.0 | 1.0 | 10.0 | 0.0 | 0.0 | 0.0 |
| Farm 4 | 0.0 | 6.0 | 0.0 | 6.0 | 0.0 | 1.0 | 0.0 |
| Farm 5 | 0.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Figure 3.5.** Results of the assessment of wounds due to ear tagging in 48 male and female calves assessed directly after ear tagging (day 0) (n = 48) and 7 (n = 48), 21 (n = 25), and 42 (n = 25) days after insertion on five typical Western German dairy farms in Study 2. Significant differences between the assessments for each wound healing characteristic (listed in the legend) are highlighted by different letters. Estimated wound signs by the five participating farmers are shown below the figure.

Furthermore, increased bedding hygiene scores (higher soiling) correlated with the occurrence of resistance during the inspection ($r = 0.23$, $P = 0.004$), swelling ($r = 0.28$, $P < 0.001$), and inflammation ($r = 0.39$, $P < 0.001$). The diarrhea score of the calf health scoring system positively correlated with the occurrence of incrustation ($r = 0.31$, $P < 0.001$) and bleeding ($r = 0.25$, $P < 0.001$). Calves' heart girth correlated with incrustation ($r = 0.19$, $P < 0.02$).

## 3.6. Discussion

### 3.6.1. Ear tag position and wound lesion prevalence

Previous studies and ear tag manufacturers recommend placing ear tags for calves in the middle of the ear between the two ear ridges as evidence indicates that this area is largely free of nerves and blood vessels (Rashid et al., 1987; Johnston and Edwards, 1996; Allflex, 2017). In Study 1, more than a third of all ear tags assessed were placed on the ridge (39.8%), which was likely because of handling issues during ear tag insertion rather than intentional placement on the ridge. For example, all five farmers in Study 2 aimed to place ear tags between the ridges. Furthermore, holding the calf between the legs during insertion might help improve the placement of ear tags as the two farms that used this method were able to place the ear tags of the calves assessed very near the intended position (Study 2). This is also consistent with the statements of all surveyed farmers who reported that calf movement of the calf during the insertion leads to the misplacement of ear tags. Our research calls for further investigation of the optimal restraint method to increase the accuracy of ear tag positioning.

Study 1 showed that 53.1% of all calves had clinical signs of wound lesions (wound lesion scores 2 and 3) on at least one ear. Wendl et al. (2011) evaluated the ears of ear-tagged sheep 4 weeks after insertion. They found similar results, with 88% and 27.2% of 7 008 sheep suffering from inflammation and incrustation around the point of insertion, respectively. In contrast, a study conducted by Johnston and Edwards (1996) on 91 3-week-old calves tagged with plastic ear tags reported changes in only one calf (1.1%, hemorrhage around the tag). However, this study was conducted on a single farm, which might have caused this low prevalence as Wendl et al. (2011) showed that prevalence varies greatly across farms. Wendl et al. (2011) also reported other clinical signs in sheep (skin alterations, pulling of ear tags through the ear tissue, or an increase in the insertion hole size), although with a much lower prevalence (< 5%). Salina et al. (2016) observed adverse events from ear tagging, such as severe ear necrosis, in 15.8% of 101 ear-tagged 5–14-month-old cattle. In the present studies, severe alterations of ear tissue (e.g., squeezed ear ridge tissue or incisions of flags into ear ridges) were also seen. These severe changes were not observed in Study 2; however, this study was conducted on only five farms, and the person responsible for ear tagging was aware that the results would be evaluated. Nevertheless, 7 and 14 days after insertion, around 80% of calves showed signs of incrustation and more than 20% had pus discharge. In addition, resistance during the inspection was observed, indicating that the wound lesions caused pain in the animals. Studies on wound healing in disbudded calves (thermocautery) have shown that the wound tissue is more sensitive than other tissues even 9–15 weeks after disbudding (Adcock and Tucker, 2018; Casoni et al., 2019). Although the duration of wound healing in ear-tagged calves is less studied than that of disbudding and most likely less painful (Stewart et al., 2013), 18.5% of calves aged > 10 weeks showed the signs of ongoing wound healing in Study 1, indicating that the duration of wound healing in ear tagging might be comparable. To our knowledge, the beneficial effect of topical disinfection of wounds is still discussed (Atiyeh et al., 2009; Davidson, 2015), and the effect on ear tag wounds has not yet been researched. Nevertheless, it is recommended in some manuals to enhance wound healing (Allflex, 2017). Thus, more research is needed to close these knowledge gaps.

### 3.6.2. Risk factors

*Farm size*

An explanation for the lower ORs for large- and medium-sized farms found in Study 1 could be that more calves are ear tagged on those farms and thus the ear tagging person is more experienced in performing the process. Wendl et al. (2011) also found large differences between farms (inflammation around the ear per farm:7.1%–51.6%), which they explained based on the observed differences in housing environments and microbial flora.

*Calf age*

The highest prevalence for ear tag scores 2 and 3 was noted in Study 1 for 3- to 4-week-old and up to 2-week-old calves, respectively. With increasing age, the prevalence decreased in both studies, and thus the odds for higher ear lesion scorings in Study 1. To our knowledge, no studies have analyzed the wound healing process of ear-tagged calves or its duration. However, wounds due to hot-iron disbudding require 9 weeks to re-epithelialize, with most exudative and granulations being observed between weeks 3 and 5 (Adcock and Tucker, 2018). Two other studies evaluated the wound healing process after horn amputation and castration (van der Saag et al., 2018a and 2018b) and found that wound scoring decreased from day 1 and was significantly lower on day 7. Although the periods used in those studies differed from that used in our study, all studies reported the highest prevalence shortly after the procedure, followed by a decrease over time. Ear tagging differs from other procedures in calves (e.g., disbudding, castration, and tail docking) as no tissue is removed. In contrast, an artificial tag is inserted by penetrating and ripping the ear tissue, making irritations and wound healing more variable (Johnston and Edwards, 1996). Inspections of wound healing processes by the farmer after 2 weeks could be useful to evaluate ear tag management for self-monitoring or to initiate measures in case of severe wound lesions.

*Housing form and number of animals in groups*

In our study, calves housed in single groups tended to have higher odds of having a wound lesion score of 3, which could be related to calf age but also to the management on farms as farms that moved calves to group housing later also struggled with calf management in general (Hayer et al., 2021a).

The increased odds for larger groups in Study 1 could be associated with behavioral differences in group-housed calves. For example, studies have reported cross-sucking of ears in group-housed calves (Lidfors, 1993; Jung and Lidfors, 2001). Although Jensen and Budde (2006) only observed numerically more cross-sucking in groups of six compared to pair housed calves, they observed higher competition for milk and more changes between teats, which was intensified by lower milk allowance. Powerful movements of or against the ear tags during feeding may delay wound healing as excessive skin movement disrupt wound healing. In this regard, providing a sufficient amount of milk by suckling – the main drivers of cross-sucking – may not only improve animal welfare by allowing natural behavior and sufficient feed consumption (Jensen and Budde, 2006) but also potentially lower the risk of ear tag wound lesions.

*Ear tag position*

Ear tag position is the most frequent and often the only described influential factor in scientific publications and users' manuals on ear tagging. A study on the anatomy of animal's ear auricle recommended the area between the two main ridges (Rashid et al., 1987). Field studies have found a lower prevalence of wound lesions at this position (Wendl et al., 2011), and experimental studies have placed ear tags according to this recommendation (Johnston and Edwards, 1996; Stewart et al., 2013; Lomax et al., 2017). In line with these recommendations, placing ear tags on the ridge highly significantly increased the odds for wound lesion score 2 and numerically for score 3 in Study 1. Nevertheless, ear tag lesions were also seen due to mechanical friction caused by ear tags placed between the ridges (Figure 3.1D).

Furthermore, Study 2 indicates some farmers preferred a tag position close to the ear base, whereas others placed the ear tags at the center. Different arguments apply to the optimal position between the ridges: a position near the ear base is critically discussed as the density of nerves and blood vessels is highest in this region (Rashid et al., 1987), a centered position to close to one of the ridges can lead to incisions of ear tag flags into the ridges (Figure 3.1D), and a position near the ear margin is more prone to loosely fits and ear tag losses (Edwards and Johnston, 1999). Therefore, more studies are warranted regarding the exact placement of ear tags to define the best position to minimize pain during insertion, enhance wound healing over time, and prevent discomfort or ear tag loss.

*Score of the other ear*

An ear tag lesion score of 2 or 3 in the other ear increased the odds of the same scoring, supporting the importance of animal-specific characteristics such as calf age and health status. The linkage of wound lesions in both ears reinforces our recommendation to check the wound healing of tagged ears after 2 weeks, as the affected animals will most likely suffer from two wound lesions rather than one. Delayed wound healing might also be caused by general effects such as immune system weakness or impaired hygienic conditions. First indications of this hypothesis were found in Study 2 as low bedding hygiene and diarrhea correlated positively with wound lesion signs such as incrustation or swellings.

*Additional effects*

Although several studies have reported differences in calf management between male and female calves (Renaud et al., 2017; Hayer et al., 2021a) and farmers in Study 2 reportedly differentiated between male and female calves in ear tagging, no significantly higher odds for ear tag lesions in male calves were found in Study 1.

Furthermore, Study 1 showed no significant effect of the stated time of ear tag insertion on the odds for higher wound lesion scores. Nevertheless, the first hours after birth are particularly important for newborn calves, as they rely on the uptake of colostrum to establish passive immunity and protection against pathogens (Godden et al., 2019). Performing painful procedures during this period may increase the risk of insufficient colostrum uptake and failure of passive transfer (Torrey et al., 2009). Furthermore, adverse handling of animals such as painful procedures increases animal's fear of humans (Rushen et al., 1999). Although, to our knowledge, no study has investigated the effect of early ear tagging on calves' fear of humans, ear tag insertion as one of the first contacts between the calf and stock person may negatively affect their relationship.

The results of Study 2 indicate that farmers differ in their ear tag insertion practice (e.g., the restraint of calves or position of calves during insertion), which may influence the fit and placement of ear tags and should be evaluated in further studies. Furthermore, different tag manufacturers are used on farms and between farms. Tag material and design have been shown to influence ear tag wound healing in calves and other species (Johnston and Edwards, 1996; Wendl et al., 2011; Salina et al., 2016). Tag manufacturer has not been recorded and evaluated as a risk factor in Study 1, which is a limitation of our study. However, the state control associations of the visited region require farmers to use the ear tags of Caisley or Allflex, which are both very similar in design and follow the overall design requirements of the EU.

Finally, Wendl et al. (2011) discussed the importance of sufficient space between ear tissue and tag flag to ensure air flow and optimal wound healing. Insufficient space between tag and tissue may also explain the mechanical friction and tissue deformation observed in Study 1 and should be evaluated in further studies.

The observer was included as a variable to address inter-observer reliability, and calves assessed by observer 2 had lower odds for wound score 3. However, these results must be interpreted with care as distinguishing between farm and observer effect was impossible.

### 3.6.3. Implications for the improvement of animal welfare

Study 1 showed that signs of wound lesions in unweaned calves are common, even in calves aged > 10 weeks. Several factors have been shown to reduce the risk of wound lesions (i.e., farm size, calf age, housing form, group size, and other ear's scoring); these should be evaluated in further studies to minimize the risk of wound lesions. Most wound lesions were observed 2 weeks after insertion, which may be used as a time point to assess wound healing in order to ensure normal wound healing and treat severe wound lesions. Routine ear tag checkups could also increase farmers' awareness of wound lesions due to ear tagging – which seems to be currently lacking – and thereby improve animal welfare. Studies on animal welfare have shown that stock persons who are sensitized to animal welfare, treat calves better and implement more management recommendations (Lensink et al., 2000; Hayer et al., 2021a). Furthermore, applying pain medication during ear tag insertion and disinfecting the ears and tags before insertion reduce pain during insertion and improve wound healing (Caja et al., 2004; Numberger et al., 2016; Lomax et al., 2017; Sheil et al., 2021).

Ultimately, and similar to other painful procedures in animals (e.g., castration or disbudding), the largest improvement would be achieved by forgoing invasive measures and implementing alternative measures. Biometric identifiers such as muzzle prints and iris patterns have been studied and identified as potential identifiers of individual cattle with high accuracy and causes minimal harm to the animal (reviewed by Awad, 2016). However, until noninvasive methods for identification are validated and implemented, it appears necessary to minimize the impairment of animal welfare by the current means of identification, for which the present study offers effective approaches.

## 3.7. Ethics approval

This study was conducted following the ethical standards and data privacy agreement of the University of Bonn (University of Bonn, 38/2018), and federal and institutional animal use guidelines (FF AZ 01K 1901 201912).

## 3.8. Data and model availability statement

In this manuscript and the additional supplementary files, all relevant data are included and presented. The data used in the two studies and the R code used for calculating the ORs in Study 1 are published and free accessible on the official repository "RADAR" (Hayer and Steinhoff-Wagner, 2021; https://doi.org/10.22000/518).

## 3.9. Acknowledgements

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# 4. Influences on the assessment of resource- and animal-based welfare indicators in unweaned dairy calves for usage by farmers

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## 4.1. Abstract

Consumers, industrial stakeholders, and the legislature demand a stronger focus on animal welfare of all livestock at the farm level by using suitable indicators in self-assessments. In order to deduce farms' animal welfare status reliably, factors that influence indicators' results need to be identified. Hence, this study aimed to apply possible animal welfare indicators for unweaned dairy calves on conventional dairy farms with early cow-calf separation and evaluate influencing factors such as age and sex of calves or climatic conditions on the applied indicators' results. An animal welfare assessment using seven resource-based and 14 animal-based indicators was conducted at 42 typical Western German dairy farms (844 calves) in 2018 and 2019 by two observers. The effect of influencing factors was calculated by binary and ordinal logistic regressions and expressed as odds ratios. Although every unweaned calf was assessed during the farm visits, most farms had relatively few unweaned calves (average number of calves ± standard deviation = 20.1 ± 6.7 calves), with six farms having not more than ten calves. The small sample sizes question the usage of those indicators to compare between farms and to set thresholds at farm level. Only one assessed indicator (cleanliness core body) was not statistically affected by the evaluated influencing factors. Calf age was identified as the most decisive factor, as it affected 16 of 21 evaluated indicators and calf age distribution on-farm varied greatly. Climatic conditions (ambient temperature and rainfall) influenced resource-based indicators such as access to concentrate and water or the cleanliness of feeding implements and bedding as well as animal-based cleanliness indicators and the occurrence of health-related impairments such as coughing and diarrhea. The authors found differences between calves on farms assessed by the different observers in resource-based hygiene indicators but also in animal-based indicators like hyperthermia or hypothermia, highlighting the need for further evaluation of quality criteria in dairy calf welfare assessments. Nevertheless, animal welfare assessments by farmers themselves could be useful tools to sensitize farmers to animal welfare and thereby improve calves' welfare.

***Keywords:*** consistency over time, self-assessment, sample size, welfare indicators, confounding factors

## 4.2. Introduction

Consumers' demand for animal-friendly production systems has risen over the past decades, forcing the dairy industry to improve its production systems' welfare (Weary & Keyserlingk, 2017). Animal welfare assessment protocols have been developed to evaluate animal welfare at the farm level to ensure high animal welfare standards (Krueger et al., 2020). The Welfare Quality® protocol for dairy cows, developed in the EU-funded Welfare Quality® project, incorporates social, scientific, and industrial demands focusing on the animal itself by using primarily animal-based indicators (Blokhuis et al., 2010). However, dairy calves are not included in this program, despite their unquestionable importance (Krueger et al., 2020) and inherent presence on dairy farms.

The focus on animal welfare indicators increased since then as more assessment protocols were developed by scientists for different species or husbandry systems (Can et al., 2017; Berteselli et al., 2019; Barry et al., 2019a). In 2014, the assessment of animal welfare indicators by farmers themselves was firstly included in animal welfare regulations as the German Animal Welfare Act was revised. The revised § 11 (8) of the German Animal Welfare Act demands collecting and assessing suitable animal-based animal welfare indicators by farmers for every livestock species. However, neither suitable indicators nor the form of the assessment or the assessment interval is specified by law. To solve this, the German Association for Technology and Structures in Agriculture (KTBL) developed several sets of animal welfare indicators for the different livestock species, including one for reared calves consisting of eight indicators (Brinkmann et al., 2016). Currently, no results of an application of this self-assessment protocol have been published yet. Also, important aspects of dairy calves' welfare, such as individual health status, are missing, and national legal requirements that were not convertible into animal-based indicators (e.g., access to fresh feed and water) were left aside. Although, Germany is currently the only country requiring farmers to conduct welfare self-assessments, it could be seen as a role model for other countries as social and political awareness for animal welfare is already high (Vogeler et al., 2018).

Using animal welfare indicators for comparison between farms and in third-party verifications of quality programs with fixed thresholds is only possible when indicators show sufficient reliability (Waiblinger et al., 2001; Pfeifer et al., 2020). Recently, projects aimed to assess intra- and interobserver reliability and retest reliability for established indicator programs of the Welfare Quality® project (Kirchner et al., 2014; Czycholl et al., 2016) or the KTBL protocol for pigs (Pfeifer et al., 2020). Another vital quality criterion is consistency over time, which describes that the assessments' results represent the long-term welfare state of farms (Kirchner et al., 2014). Despite limitations in reliability or consistency over time, animal welfare indicators are increasingly used in practice for benchmarking, for third-party verifications in quality programs, or self-assessments (Pfeifer et al., 2019; Krueger et al., 2020).

Animal welfare assessment protocols including animal-based welfare indicators for unweaned calves were only recently proposed (Barry et al., 2019a), and no validation has been made yet. Poor reliability and consistency over time of animal welfare indicators can be associated with the indicator's dependence on animals' characteristics (e.g., sex or age) or conditions on-site during the visit (Mullan et al., 2009). Calves in general, and especially unweaned calves are fast-growing animals, undergoing considerable changes in the gastrointestinal tract and are exposed to different health risks depending on their age (Svensson et al., 2003; Windeyer et al., 2014; Wickramasinghe et al., 2019). Also, and contrary to piglets, calves are mostly housed in outdoor or semi-outdoor environments and therefore influenced by ambient climatic conditions, which might influence calves' welfare (Roland et al., 2016). Influencing factors such as calf age or the environmental conditions at the time of an assessment affected the reliability or the consistency over time of animal welfare assessments on farm level in previous studies (Mullan et al., 2009; Kirchner et al., 2014; Can et al., 2017; Berteselli et al., 2019) and need to be evaluated to control for them.

The present study aimed to test possible resource- and animal-based animal welfare indicators to be used in assessments for unweaned dairy calves under practical conditions on Western German dairy farms. Secondly, we aimed to identify influencing factors on those indicators' results by analyzing the effect of group size, calf sex, age, climatic conditions before and during the visit, and the observer.

## 4.3. Material and methods

This study was conducted in accordance with federal and institutional animal use guidelines (Az. 84 - 02.05.40.16.038), the data privacy agreement (University of Bonn, 38/2018) and ethical standards.

### 4.3.1. Resource- and animal-based indicators

Firstly, an assessment protocol including management-, resource- and animal-based indicators was designed based on international and national welfare assessment systems (e.g., Welfare Quality, 2009; Vasseur et al., 2012; Brinkmann et al., 2016) and publications on the welfare of calves (Table 4.1 and 4.2; Supplemental Table S7.5). Resource-based indicators were mainly adapted from Vasseur et al. (2012). The indicators diarrhea, coughing, hypothermia, and hyperthermia were included as a simplified and shorter version of the health scoring method from McGuirk, University of Wisconsin (https://fyi.extension.wisc.edu/heifermgmt/files/2015/02/calf_health_scoring_chart.pdf).

**Table 4.1.** Evaluated resource-based animal welfare indicators (n = 9) used to assess dairy calf housing conditions on 42 Western German dairy farms.

| Indicator | Definition | Score levels |
|---|---|---|
| Access to roughage | Calves were provided with additional roughage (straw bedding excluded) | 0 = No access to additional roughage<br>1 = Access to additional roughage |
| Access to concentrate | Calf having access to concentrate | 0 = No access to concentrate<br>1 = Access to concentrate |
| Access to water | Calf having access to water | 0 = No access to water<br>1 = Access to water |
| Cleanliness of milk bucket | Appearance and condition of each calf´s milk bucket | 0 = No soiling visible<br>1 = Minor milk residues visible<br>2 = Coarse soiling |
| Cleanliness of feeding trough | Appearance and condition of each calf´s feeding trough | 0 = No soiling visible<br>1 = Minor soiling<br>2 = Coarse soiling and spoiled feed left |
| Cleanliness of water trough | Appearance and condition of each calf´s water trough | 0 = Clean drinking water<br>1 = Low turbidity, feed residues<br>2 = High turbidity, feed residues in water, visible biofilm development |
| Cleanliness bedding | Appearance and condition of each calf´s bedding | 0 = Fresh, clean, dry bedding<br>1 = Minor soiling, slightly damp<br>2 = Coarse soiling, wet spots |

Animal-based hygiene indicators can provide valid information on bedding quality, which is important for disease prevention, thermoregulation, and resting behavior of calves. As no uniform hygiene assessment exists, three different scorings (core body, carpal joints, and claws) were integrated in this study. Beside the unquestionable value of behavioral indicators, at the time of the study an integration of behavioral indicators for calves on farm was hampered by their ongoing evaluation status but should be addressed in future studies. Assessment and results of management-based indicators are described in detail in a related publication (Hayer et al., 2021). Only resource- and animal-based indicators were assessed, which farmers could use without extensive training or additional material.

**Table 4.2.** Evaluated animal-based animal welfare indicators (n = 14) used to assess unweaned dairy calves' animal welfare on 42 Western German dairy farms.

| Indicator | Definition | Score levels |
|---|---|---|
| Cleanliness core body[1] | Cleanliness of core body, one site was chosen randomly | 0 = Less than 25% of surface is dirty<br>1 = More than 25% of surface is dirty |
| Cleanliness carpal joints | Cleanliness of surface around the carpal joints | 0 = Clean carpal joints<br>1 = Minor soiled carpal joints<br>2 = Coarse soiling, wet carpal joints |
| Cleanliness claws | Cleanliness of all four claws | 0 = Clean claws<br>1 = Slight soiling around the claws<br>2 = Thick crust of dirt around claws |
| Nesting score[1] | Evaluation of amount and quality of bedding | 0 = Limbs not visible in lying calves<br>1 = Limbs partly visible in lying calves<br>2 = Limbs fully visible in lying calves |
| Underdevelopment/ runt[1] | Evaluation of general appearance (muscles, visibility of ribs, coat) | 0 = Lack of muscles, ribs visible, dull coat<br>1 = Good muscles, ribs not visible, shiny coat |
| Hypothermia | Rectal temperature below 38.5°C | 0 = Rectal temperature > 38.5°C<br>1 = Rectal temperature < 38.5°C |
| Hyperthermia | Rectal temperature above 39.5°C | 0 = Rectal temperature < 39.5°C<br>1 = Rectal temperature > 39.5°C |
| Ear tag wounds | Evidence of wound healing disorder around the ear tag | 0 = No clinical sign of wound healing disorder<br>1 = Discharge of pus or blood, deformation of tissue |
| Horn bud inflammation[1] | Evidence of wound infection around the removed horn bud | 0 = No clinical sign of inflammation<br>1 = Reddening, swelling, or pus discharge around the removed horn bud |
| Navel inflammation | Evidence of navel infection | 0 = Normal, pain-free to handle<br>1 = Swelling, inflammation of navel area |
| Diarrhea | Evidence of diarrhea | 0 = Solid or paste-like feces<br>1 = Watery fluid feces, pungent smell |
| Coughing | Presence of a cough | 0 = Normal breathing<br>1 = Spontaneous or continuous coughing |
| Visible skin injuries | Assessment of abrasions or skin damage | 0 = Absence of lesions or wounds<br>1 = Visible lesions or wounds |
| Sucked teats | Evidence of sucked teats | 0 = Normal tissue around teats<br>1 = Swollen tissue around teats |

[1]Indicator based on (Brinkmann, et al., 2016).

### 4.3.2. Farm visits

A total of 21 resource- and animal-based indicators (seven resource-based indicators, 14 animal-based indicators) were applied in a single animal welfare assessment of a total of 844 unweaned dairy calves held at 42 dairy farms in the regions of Rhineland-Palatinate (n = 22) and North Rhine-Westphalia (n = 20) in two time periods during hibernal climatic conditions (First: November 2018 to April 2019; Second: October 2019 to December 2019).

This study was limited to farms of the two regions in Western Germany as characteristics of German dairy farms differ by region in breeds used, farm size, and structure. Approximately 1,800 and 5,600 dairy farms are located in Rhineland-Palatinate and North Rhine-Westphalia, respectively. The average herd size in these regions is relatively similar, with 63 and 74 cows, respectively (BMEL, 2019). Farm selection and farm visit procedure are described in detail in Hayer et al. (2021). In summary, farms, which participated in previous studies administered by the University of Bonn, were contacted, asked for participation in a study about calf welfare, and a visit was scheduled in consultation with the farmer. Upon arrival, stockpersons were interviewed (Hayer et al., 2021), followed by an assessment of the husbandry system and the recording of animal welfare indicators without the presence of the stockperson. Assessments were performed by one of two researchers, who were used to working with livestock. The assessment of housing facilities included the housing system (e.g., single, pair, or group housing), the housing position, the feeding implements in both single and group housing, and the level of social contact between adjacent calves. The two observers trained the developed animal welfare assessment protocol on two farms with 60 calves. During and after the training assessments, observers discussed the interpretation, and classification of the used indicators to assure a common understanding. Like other recent studies, only unweaned dairy calves were assessed as unweaned and weaned calves differ greatly in aspects of physiology, feeding, behavior, and husbandry systems (Barry et al., 2019a). All unweaned calves on each farm were examined, except for three farms (n > 40 calves), on which the number was limited to two-third of the assessable calves due to limitation in time and resources. In this case, calves from each age segment were chosen by rolling a dice and excluding all calves getting a one or a four.

### 4.3.3. Influencing factors

This study focused on the influencing effect of the observer, group size, calf sex, age, the ambient climatic conditions before and during the assessment. Ambient climatic conditions at the assessed farms were extracted from the open-access data bank of the German Meteorological Service for the two days before the visit and the day of the visit. The linear distance of farms to weather stations ranged from approximately 1 km to 20 km. From this data, the average of these three days was calculated for minimal temperature (°C), maximum temperature (°C), average temperature (°C), rainfall (L/m$^2$), number of daily hours of sunshine (h), and maximum wind velocity (km/h). Evaluated characteristics of calves were age, which was extracted from farmers' records, and sex, which the observer assessed during the protocol.

Furthermore, the housing form (individual, pair, or group housing) and the number of calves housed together (continuous variable) were recorded.

### 4.3.4. Data analysis

Descriptive results were illustrated as percentages of scores or farms for qualitative variables, while quantitative data were described using means with standard deviation. The number of observations (respectively, the number of calves assessed) differed due to each indicator's limitations. For example, the nesting score from Brinkmann et al. (2016) can only be assessed for lying animals, or the wound healing of disbudding or ear tagging can only be evaluated for an animal that underwent these procedures. Each indicator was assessed for each calf whenever possible and was differentiated by a scheme with either two or three-level scoring (0, 1 and 0, 1, 2, respectively). A linear model was created to detect and adjust to multicollinearity between the evaluated influencing factors using the assessed influencing factors as independent variables and the animal welfare indicator as the dependent variable for each animal welfare indicator. For each model and variable, the variance inflation factor was calculated using the "vif"-function of the "car" package (Version 3.0-10) in R (Version 4.0.3). All influencing factors with a variance inflation indicator greater than five, indicating critical multicollinearity levels, were removed from the analysis.

Influencing variables left after this process and included in the following analysis were: "group size," "calf sex," "calf age," "average ambient temperature," "average rainfall," and "observer." The influencing factor "observer" was included in the statistics to account for the possible effect of the two different investigators. However, due to the assessment of each farm by only one observer, farm effects cannot be excluded from the observers effect. For analyzing the effect of influencing factors on the assessed animal welfare indicators, logistic regressions were calculated. Ordinal indicators (cleanliness of milk bucket, feeding trough, water trough and bedding, cleanliness of carpal joints and claws; and the nesting score) were evaluated using R's "polr" function of the "MASS" package (Version 7.3-53) to perform an ordinal logistic regression as described by UCLA (2020). For binary indicators (access to concentrate, roughage and water, cleanliness core body, runt, hyperthermia, hypothermia, ear tag wounds, horn bud inflammation, diarrhea, coughing, visible skin injuries; and sucked teats) a binary logistic regression was applied using R's "glm" function of the "MASS" package based on Rawat (2017). Calculated logistic odds ratios and confidence intervals were exponentiated to get odds ratios and confidence intervals. It is important to account for the different scales of influencing factors. In the case of nominal influencing factors (e.g., observer one vs. observer two or male vs female), the calculated odds ratio describes one level of the influencing factor's effect compared to the other level. For example, an odds ratio of 2.0 for the factor "observer" can be interpreted so that the risk for a higher outcome level is two times higher for observer two than observer one. However, in the case of continuous influencing factors (e.g., age or average temperature), odds ratios describe the increase or decrease of probabilities for a higher outcome level with every unit of the influencing factor - e.g., in the case of calf age with every day. Odds ratios were considered statistically significant at $P \leq 0.05$, with $P \leq 0.01$ indicating statistically highly significant odd ratios and $0.05 < P < 0.1$ indicating a statistical tendency.

## 4.4. Results

### 4.4.1. Descriptive results

Detailed characteristics and calf management of enrolled farms have been described previously (Hayer et al., 2021). Of the 42 assessed farms, 24 were assessed by the first observer and the other 18 by the second observer. The ambient climatic conditions and the distribution of numbers of calves assessed per farm and their sex are shown in Table 4.3.

**Table 4.3.** Distribution of evaluated influencing factors on animal welfare assessments in unweaned dairy calves on 42 Western German dairy farms.

| Variable (unit, number of farms) | Mean ± SD | Minimum | Median | Maximum |
|---|---|---|---|---|
| Average temperature[1], °C (n = 40) | 6.1 ± 3.3 | 0.0 | 5.0 | 19.9 |
| Rainfall[1], L/m$^2$ (n = 42) | 2.2 ± 1.8 | 0.0 | 1.5 | 8.7 |
| Amount of daily sunshine[1], h (n = 38) | 2.0 ± 1.4 | 0.0 | 1.4 | 9.7 |
| Maximum velocity[1], km/h (n = 36) | 5.4 ± 1.1 | 3.0 | 5.3 | 7.3 |
| Number of calves assessed (n = 42) | 20.1 ± 6.7 | 5.0 | 19.0 | 59.0 |
| Percentage of female calves, % (n = 42) | 83.0 ± 11.4 | 52.0 | 85 | 100.0 |
| Percentage of male calves, % (n = 42) | 17.0 ± 11.4 | 0.0 | 15 | 48.0 |
| Average age of calves assessed, d (n = 42) | 42.1 ± 9.2 | 14.6 | 42.6 | 66.3 |

[1]Average ambient environmental conditions for the day of the visit and 2 d before the visit were extracted from official weather stations, which differed in assessed parameters.

An average of 20.1 calves was assessed per farm, which was predominantly female. Six of the 42 farms reared bull calves, whereas the other 36 farms sold their bull calves at approximately 14 days of age. The average age of male calves was 25.2 d (range 1–107 d) and 47.3 d (range 1–128 d) for female calves. Reared calves were weaned with an average age of

10.8 ± 1.6 weeks. The age distribution of unweaned calves on the farm differed greatly between the 42 farms (Figure 4.1).

All calves were first housed in individual (n = 40) or pair housings (n = 2) after birth (time of separation between 1 h and > 1 d p.p.) and then in groups of 7.2 ± 2.9 calves. The average duration of individual and pair housing was 16.9 ± 5.4 d. Calf hutches were the only housing type used by 38.1% of the farms visited, calf pens were the only housing type used by 38.1% and 23.8% used both Most common was housing the groups in deep straw stables inside a semi-closed barn (50%) followed by deep straw stables in a barn with an open side or group hutches without a roof to cover the enclosure (23.1% each). Group hutches under a roof and group hutches inside a barn were less commonly found at the farms (14.3% and 4.8%, respectively).

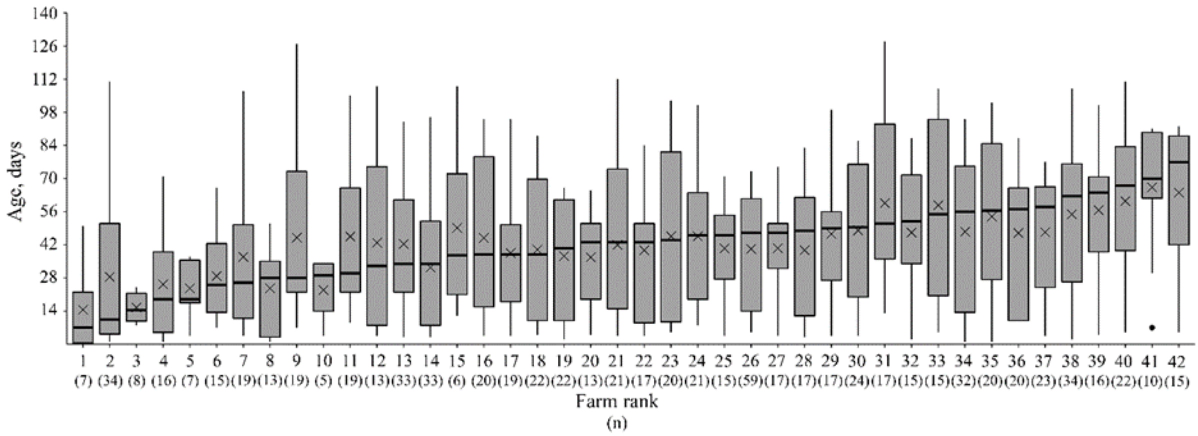


**Figure 4.1.** Distribution of calf age on 42 Western German dairy farms ranked according to the median calf age. The mean calf age for each farm is visualized by a “x” in each boxplot. The black line inside each box represents the media; lower and upper hinges represent the 25th and 75th percentiles, respectively. The whiskers end at the lowest and highest values that are no outliers (marked as dots). The number of observations (n) for each farm is displayed below the farm ranks.

In total, 21 animal welfare indicators were assessed in 844 unweaned dairy calves. The distribution of the results of resource-based indicators is shown in Figure 4.2. High proportions of calves had no access to water, roughage, or concentrate (28.5%, 34.1%, and 41.0%, respectively). Regarding evaluating the housing environment's cleanliness, milk buckets were identified as the main concern, with over 75.8% of milk buckets having minor or coarse soiling, while feed troughs, and bedding were most often scored as clean.

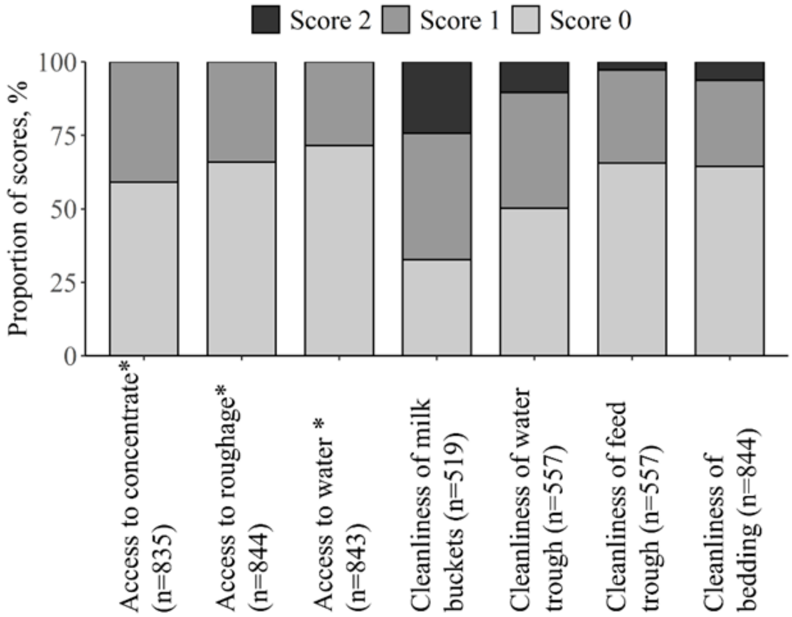


**Figure 4.2.** Percentage distribution of the sores (0, 1, 2) of seven resource-based indicators to assess the housing environment of unweaned dairy calves (n = 844) on 42 Western German dairy farms. Marked indicators (*) were defined only by a two-level scoring system (0, 1).

Results of animal-based indicators are displayed in Figure 4.3 as a proportion of given scores. The calves' core body was scored as clean in the case of 93.2% of calves, whereas carpal joints and claws were more often soiled (45.1% clean and 49.7% clean, respectively). Clinical signs of impaired animal health were below 15% (diarrhea: 14.4%, hypothermia: 12.0%, skin injuries: 8.1%, coughing: 7.9%, hyperthermia: 7.3%, navel inflammation: 7.2%, sucked teats: 3.3%, and runt: 1.9%), except for ear tag wound inflammation and horn bud inflammation, which was recorded for 53.1% and 18.2% of all calves assessed, respectively.

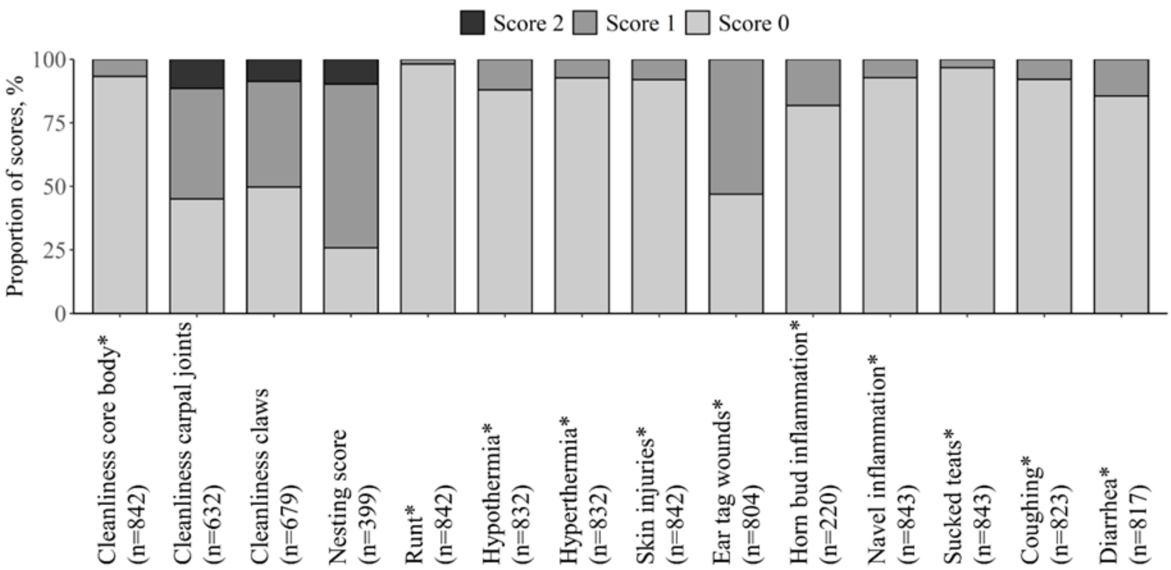


**Figure 4.3.** Percentage distribution of the sores (0, 1, 2) of 14 animal-based indicators to assess the welfare of unweaned dairy calves (n = 844) on 42 Western German dairy farms. Marked indicators (*) were defined only by a two-level scoring system (0, 1).

### 4.4.2. Effect of influencing factors

The calculated effect of recorded influencing factors is shown as ORs in Figure 4.4. Due to multicollinearity reduction, only six influencing factors were left in the final model and were evaluated. A detailed description of the calculated OR is provided as additional material (Supplemental Table S7.6).

ORs for denied access to concentrate, roughage, and water decreased with the number of animals per group (OR: 0.56 to 0.83). In contrast to the cleanliness of feed troughs, which had decreased odds to be rated as soiled in decreasing group sizes (OR: 1.09), milk buckets and bedding had lower odds to be rated as soiled in smaller groups (OR: 0.79 and 0.92, respectively).

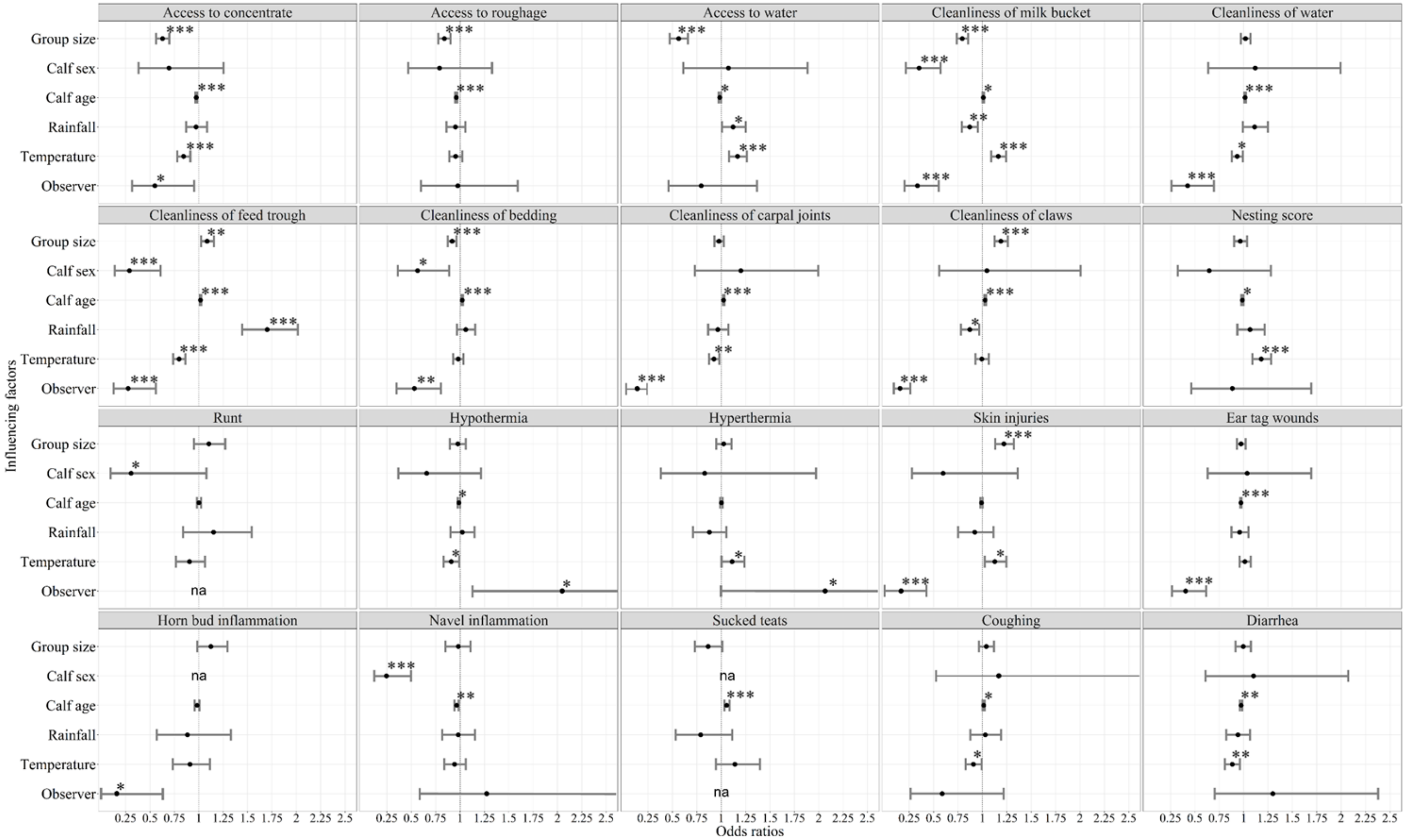


**Figure 4.4.** Calculated odds ratios for the effect of group size (animals per group), calf sex (male vs. female), calf age (d), average rainfall of the two days before the visit and the day of the visit (L/m$^2$), the ambient temperature (°C) during this period, and the observer (observer one vs. observer two) on the results of 20 animal welfare indicators, with stars, indicating statistical differences (* $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$). Odds ratios of continuous factors (group size, calf age, rainfall, temperature) represent the risk per unit increase, while the odds ratios of categorical factors (calf sex and observer) show the relationship between the factors' levels. Not assessable data is shown as "na." Dots are marking the odds ratio, and the whiskers end at the lower and upper end of the 95% confidence interval.

Calves housed in larger groups were at higher risk of higher scores in claws' cleanliness (OR: 1.19). Except for skin lesions, for which the odds increased with the number of animals per group (OR: 1.22), no effect of group size on animal health indicators was found.

Compared with female calves, male calves had lower odds for soiled milk buckets, feed troughs, and bedding (OR: 0.35 to 0.56). In contrast, being female decreased the odds of being categorized as runt (OR: 0.31) and having a navel inflammation (OR: 0.25). No effect of calf sex on horn bud inflammation and sucked teats were calculatable, as no male calves were dehorned.

The age of calves assessed influenced the evaluated indicators' results greatly as 16 of 21 assessed indicators were influenced by calf age. An increase in calf age decreased the odds of having a denied access to concentrate (OR: 0.97), roughage (OR: 0.96), and water (OR: 0.99). On the other hand, an increase in calf age led to increased odds of all other environmental and animal-based hygiene indicators (except for the core body's cleanliness), indicating heavier soiling. Also, an increased calf age entailed increased odds for high nesting scores (OR: 0.99). ORs for hypothermia, ear tag wound inflammation, navel inflammation, and diarrhea decreased with calf age (OR: 0.99, 0.97, 0.97, and 0.97, respectively), while the odds for sucked teats and coughing increased (OR: 1.06 and 1.01, respectively).

An increase in ambient temperature was associated with lower odds for a denied access to concentrate, soiled feed trough and soiled water, and higher odds of having no access to water and soiled milk buckets. Also, increasing ambient temperatures resulted in lower odds for soiled carpal joints (OR: 0.93) but higher nesting scores (OR: 1.13). Animal health indicators affected by the ambient temperatures were hypothermia, hyperthermia, visible injuries, coughing, and diarrhea (Figure 4.4). Increasing rainfall resulted in higher odds of denied access to water (OR: 1.12). Milk buckets were rated as cleaner with an increase in rainfall (OR: 0.87), whereas feed trough and calf claws had higher odds to be rated as soiled with increasing rainfall (OR: 1.70 and 0.87). No statistically significant effect of rainfall on animal health indicators was found.

Calves on farms that were assessed by observer 1 had lower odds for high hygiene-scorings (increased soiling) of environmental conditions (milk buckets, water, feed trough, and bedding; OR: 0.28 to 0.53) and the cleanliness of carpal joints and claws (OR: 0.14 and 0.16, respectively) (Figure 4.4). Hypo- and hyperthermia were recorded more frequently in calves on farms assessed by observer 2 (OR: 2.04 and 2.06, respectively). However, calves on farms evaluated by observer 1 had more often lower scores of visible skin injuries, ear tag wounds, and horn bud inflammations (OR: 0.16, 0.40, and 0.16, respectively).

## 4.5. Discussion

### 4.5.1. Animal welfare assessment in unweaned calves

Although the increasing interest of consumers in animal welfare and legal regulations requires assessing calves' welfare, to our knowledge, no standardized, evaluated recording protocol for calves or data exists. Promisingly, Barry et al. (2019a, 2019b) developed an animal welfare protocol to assess unweaned calves by trained observers. Comparable to the approach of Barry et al. (2019a), we aimed to evaluate every calf on the farm present during the visit, while Brinkmann et al. (2016) proposed an evaluation of all calves for sample sizes up to 30 calves and a representative, stepwise selection for larger calf herds. Nevertheless, this proposed threshold of 30 calves was only exceeded on seven farms. A limitation regarding the comparability is more likely posed by small farms with small dairy calf herds, as 28 of the assessed farms held not more than 20 unweaned calves and six not more than ten calves. For example, on farms with less than ten calves, an occurrence of an adverse animal welfare result in one calf already represents a proportion of more than 10%. Hampton et al. (2019) evaluated the role of sample sizes in animal welfare assessments statistically and demonstrated that far larger sample sizes are needed to determine the probability of adverse animal welfare results reliably. For a true probability of 0.15 (see low prevalence in most of the evaluated health indicators) for an adverse result, an acceptable upper limit of 0.1 and a confidence interval of 0.9, a sample size of 37 animals would be required (Hampton et al., 2019). For adverse results with lower probabilities (i.e., indicator runt in this study), far larger sample sizes would be needed (Hampton et al., 2019). Pfeifer et al. (2020) evaluated five different sampling strategies (100 evaluated animals each) for the KTBL protocol for pigs and compared the calculated prevalence of 13 indicators with the true prevalence on the farm (636 evaluated animals). They concluded that all five strategies could not predict true prevalence, and the authors proposed an extension of the sample size to 150 pigs – a sample size unreachable in unweaned calves on most German dairy farms. Thus, the usage of thresholds for the evaluated indicators for unweaned calves for on-farm animal welfare monitoring or the usage of assessments in calves for benchmarking between farmers must be seen critically.

The descriptive results of this study show that more than a quarter of all calves assessed had no access to water, additional roughage, or concentrate, although it has been shown that water and solid feed is crucial for the development of calves (Khan et al., 2016; Wickramasinghe et al., 2019). Regarding hygiene assessments, milk buckets received higher soiling scores than water, feed troughs, or bedding. Heinemann et al. (2021) evaluated the sanitation of individually housed dairy calves and identified feeding implements such as teat buckets as hygienical weak points, enhancing pathogens' spread. Most animal health impairments were relatively rare in this study. However, more than half of the assessed calves suffered from inflammations around the ear tag, an animal health issue that has not been included in the existing animal welfare assessment so far. Literature on ear tagging is relatively rare, but studies showed that ear tagging was associated with behavior that is specifically indicative of pain (Turner et al., 2020). Johnston and Edwards (1996) examined the ears of calves after slaughter and found damages to ears in 46.4% of calves tagged with metal tags and 1.1% of calves tagged with polyurethane tags lower than the prevalence found in our study. Further studies on animal welfare issues related to ear tagging are needed, and their inclusion in animal welfare protocols seems beneficial.

### 4.5.2. Effect of influencing factors

The evaluation of influencing factors showed that the results of all indicators, except for the cleanliness of the core body, were affected by at least one of the six defined factors. Our analysis showed that the odds of having access to concentrate, roughage, and water increased with the group size. Of the farms surveyed, 57.1% stated to provide only milk to individually housed calves (Hayer et al., 2021), which is similar to the results of other studies where water was not provided in single housings on 10% of farms (Johnsen et al., 2021). Other studies linking the access of concentrate or roughage to the housing form are, to our knowledge, currently missing. However, a survey from Austria reported that concentrate and roughage are provided at an age older than four weeks on 39.5% and 15.1% of dairy farms surveyed (Klein-Jöbstl et al., 2015). Increasing group size increased the risk of skin injuries, which frequently was associated with recorded symptoms of *Trichophyton verrucosum* infections. Lesions caused by *Trichophyton verrucosum* were associated with close contact among animals (Moretti et al., 1998), which aligns with our findings for increased risk factors of skin injuries in larger groups. It is important to note that we only recorded the number of calves per group but not the stocking density (available space per calf). Jorgensen et al. (2017) found a stronger relationship between calf health and stocking density than with group size, a factor worth assessing in future research.

Sex of calves as an essential factor has gained additional interest as male calves have higher risks of dystocia, relatively high mortalities, and are treated differently on dairy farms (Mee et al., 2011; Raboisson et al., 2013; Hayer et al., 2021). Our analysis showed that male calves had lower risks of soiled milk buckets, feed troughs, or bedding compared to female calves, which could be associated with the relatively young age of male calves (average of 25.2 ± 25.7 days) and the circumstance that most farms sold their surplus calves after two weeks (Hayer et al., 2021). Soiling scores reflect more long-term conditions that might explain male calves' different evaluations as they were predominantly kept for two weeks after birth (Hayer et al., 2021). Being male increased the odds of being categorized as a runt, which might be caused by different milk feeding practices for male and female calves on-farm (Hayer et al., 2021). Furthermore, a recent study among dairy producers indicated that male calves are prioritized lower than female calves due to low economic values (Wilson et al. 2021), which might impact health, growth, and development. Another possible reason could be that male calves are more likely to need assistance and have a greater likelihood of dystocia during birth, which affects further development of these calves negatively (Mee et al., 2011).

Calf age was the most significant confounder of the 21 evaluated indicators; 16 out of 21 indicators were influenced by calf age. Many of the effects reported for calf age mirror standard nutritional management changes prior to weaning. However, the calf age deviation analysis revealed that the age of unweaned calves assessed on the farm during the visit differed significantly between farms (median age of 7 days to median age of 77 days). Therefore, it seems necessary to assess calf age and interpret animal welfare assessment in calves at the farm level. Possible reasons for the differences in calf age between farms were the broad weaning age range between farms (7–16 weeks) and the additional rearing of male calves (6 of 42 farms) instead of selling bull calves with 14 days (Hayer et al., 2021). Assessed farms provided additional feed and water often relatively late (14 days postpartum) (Hayer et al., 2021), which caused the lower odds of calves having a denied access with increasing age.

Furthermore, the odds of heavier soilage increased with calf age for every resource- and animal-based hygienic indicator. Neonatal calves are especially vulnerable to infectious diseases and at risk of death during the first weeks of life (Gulliksen et al., 2009; Windeyer et al., 2014), which is also shown in the increased odds for diarrhea in younger calves by our analysis, a frequent cause for calf losses during the first weeks postpartum (Svensson et al., 2006). Also, farms surveyed reported most calf losses occurring in the first 14 days postpartum (median of 5.0%) (Hayer et al., 2021). As a result, farms might focus their workforce and attention on young calves, as older calves are more resilient, explaining the variance of hygienic indicators found for calf age and sex. Nevertheless, the odds of coughing increased with age, which has also been reported by Windeyer et al. (2014).

Ambient temperature and rainfall showed to influence the provision of concentrate and water and the cleanliness of milk buckets, water, and feed troughs. Differences caused by variance in ambient conditions might be a result of changes in dairy calf management. Barry et al. (2019b) reported a change in calf management practices at the beginning and the end of calving season in Ireland (6–12 weeks difference). Although calving seasons are uncommon on Western German dairy farms, it is imaginable that calf management on the farms surveyed changes depending on the season or climatic conditions, although it has not been reported yet. Especially in outdoor housed calves, stockpersons are exposed to climatic and sometimes uncomfortable conditions (Jorgenson et al., 1970), which might influence calf management. Also, providing calves with water during wintertime has been reported as challenging as provided water is at risk of freezing in case of low temperatures (Jorgenson et al., 1970). Most of the calves assessed were housed outdoor, and therefore animals and stockperson were at least partly exposed to climatic influences, which require different management adaptations during the different seasons (Jorgenson et al., 1970; Jorgensen et al., 2017).

On the one hand, this exposition to environmental conditions might be positive as rainfall might enhance a visual cleaning effect of calf claws due to wet surfaces' soaking effect, explaining the decreased risk for soiled claws with increasing rainfall. Whereas increased rainfall could increase the spoilage rate of feed, it could explain the effect on the cleanliness rating of feed troughs in feed troughs. Lago et al. (2006) showed an increased ability to nest, estimated with a nesting score, lowering the risk of respiratory diseases in calves in winter. Higher ambient temperatures were associated with higher nesting scores in our study, indicating that farmers provide more bedding material in case of lower temperatures. Although all farm visits were performed at the end of autumn, winter, and the beginning of spring, increased ambient temperature increased the risk of hyperthermia and decreased hypothermia risk, according to Hill et al. (2016) and Jorgensen et al. (2017). Although studies on skin injuries in calves and the association to temperature are rare, the increased risk of skin injuries with higher temperature in our study was also found in dogs' animal welfare assessments (Berteselli et al., 2019). Respiratory disease incidence and diarrhea are more prevalent during winter than in summer (Svensson et al., 2003; Windeyer et al., 2014; Medrano-Galarza et al., 2018), which supports our findings of increased odds with higher ambient temperatures for both indicators. The effects of warmer ambient temperature are likely greater, as reported for summer by Windeyer et al. (2014) or Jorgensen et al. (2017).

The observer's effect was evaluated as an influencing factor to adjust for differences in assessments due to the different observers. However, due to our study's limitations, no simultaneous assessment of the same farms by the two observers was feasible. Nevertheless, extreme odds for the observer's effect on the results of indicators might indicate a difference caused by the different observers. For example, the odds for high scorings of cleanliness indicators were 1.9–7.1 times higher for assessments of observer 2 compared to observer 1, although both trained their common understanding of the indicator scores on two farms and used the same evaluation sheet. This deviation is unlikely explainable by the variance of the different farms assessed. Furthermore, the odds for hypo- and hyperthermia were higher for assessments by observer two, indicating that the measurement of rectal temperature is influenced by the person making the measurement. Burfeind et al. (2010) evaluated the variability of rectal temperature measurements in dairy cows and found high inter-observer reliability ($r = 0.98$) but highlight possible effects of the procedure (up to 0.5°C), type of thermometer (up to 0.3°C), and the penetration depth (up to 0.4°C). Our findings support their recommendation for standardization of measurement procedures for rectal temperature measurement.

### 4.5.3. Reflection of the study design

The chosen study design and selection criteria have the advantage that it is likely to represent practical conditions in dairy calf rearing in Western Germany and showed the feasibility of data collection of the used indicators under these conditions (Hayer et al., 2021). The farms assessed were used to cooperate with researchers and, therefore, did most likely not adjust their management and housing to avoid the evaluated indicators' negative results. However, assessments of practical conditions are limited in the ability to control influencing factors and the conclusions reached are most likely not as specific as in controlled studies, in which only single variables are changed while others were kept the same. Also, due to one observer's limitation to one-time visits by one observer, true inter-observer reliability was not calculatable. However, differences were found between calves on farms assessed by the different observers (e.g., cleanliness scorings or rectal temperature measurements), highlighting the need for further studies. All assessments were conducted in late autumn, winter, and early spring, and thereby only limited conclusions can be drawn from the effect of climate as an influencing factor. In particular, the effect of summer conditions on the results of animal welfare assessments would be an interesting addition to our research, as heat stress has a major impact on animal welfare (Roland et al., 2016; Jorgensen et al., 2017) and calf management on farm might be different in summer (Barry et al., 2019b). Although macroclimate strongly influences microclimate in barns, pens, or hutches to which calves are exposed, changes in microclimate will be most likely smaller, and further studies are needed to evaluate its effect. Furthermore, this study only evaluated the effect of ambient temperature, which differs from microclimate in barns, pens, or hutches to which calves are exposed. Especially considering climate change, a stronger focus on climatic effects on calves welfare seems necessary (Roland et al., 2016).

### 4.5.4. Implications of the evaluation of influencing factors

Livestock farmers are obliged to assess livestock's animal welfare, including dairy calves on dairy farms, by using animal welfare indicators. This study aimed to determine the variance of possible resource- and animal-based indicators, evaluate influencing factors on these indicators' results, and identify associated challenges. In relation to the number of dairy cows kept, the number of evaluable dairy calves was small, limiting reliability, and comparability between farms. On small farms, individual calves account for much of the variance in the overall result. This relationship is even more critical given that the herd size of this study was relatively large (150 ± 16.6 cows) compared to Germany in general (65.3 cows) (BMEL, 2019) or other European countries. Further research on how to adjust for small calf herds could help overcome insufficient sample sizes to implement self-assessment of dairy calves. Based on the evaluation of influencing factors in this study, the general applicability of resource- and animal-based indicators to evaluate farm animal welfare for controlling or benchmarking between farms should be carefully reconsidered. It seems to be important to adjust the results of animal welfare indicators for influencing factors such as the climatic condition during the assessment or the age and sex structure of the assessed calf herd. Furthermore, inter-observer reliability of single indicators has been critically discussed (Czycholl et al., 2016; Vieira et al., 2018; Pfeifer et al., 2019) and may limit their usage in welfare assessments. One solution for the issues of small sample sizes and influencing factors could be repeated assessments during different seasons and the calculation of rolling averages as suggested by Kirchner et al. (2014). However, this would require additional effort and time by the farmers. In line with Pfeifer et al. (2019), we assume that the most significant benefit of self-assessed animal welfare indicators in calves is farmers' sensitization to animal welfare during the continuously repeated process of assessing and evaluating animal welfare indicators in their animals. Studies have shown that stockpersons' ability to empathize with calves contributes to better handling, management, and productivity of calves (Lensink et al., 2000; Hayer et al., 2021). Anneberg et al. (2013) conducted an interview study of Danish animal welfare inspectors, in which they highlighted the importance of farmers' motivation to improve animal welfare. The assessment and evaluation of animal welfare indicators by farmers could enhance this ability and improve animal welfare. Although farmers monitor their animals daily, additional self-assessments can sensitize farmers to aspects that are not routinely monitored (e.g., ear tag and horn bud wounds or specific cleanliness indicators). However, studies indicate that some farmers might see the obligation of animal welfare self-assessments as an insult and interference into their stockmanship (van Dijk et al., 2018), which might hinder positive effects. Informing farmers about the benefits of self-assessments might help to overcome this barrier.

In conclusion, the assessment of animal welfare by resource- and animal-based indicators in unweaned dairy calves showed to be hampered by the relatively small calf herds on the dairy farms visited and their variation regarding calf age and sex. Group size, calf sex, age, climatic conditions at the time of the farm visit as well as the role of the observer, were identified as influencing factors on the result of animal welfare indicators. Although the usage of animal welfare indicators from self-assessment for controlling or benchmarking animal welfare of calves on a farm level seems critical, resource- and animal-based welfare indicators might be useful tools to sensitize farmers to the welfare of calves via the assessment itself and thereby improving animal welfare.

## 4.6. Acknowledgments

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# 5. Short communication: On-farm applicability of behavioral welfare assessments for group-housed unweaned dairy calves

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## 5.1. Abstract

Evaluating animal behavior is an essential part of animal welfare assessments on farms. However, there is no standard method for behavioral assessments of group-housed unweaned dairy calves. The aim of the study was to evaluate and compare the reliability and feasibility of four assessment methods modified for on-farm usage. We compared standard and simplified Qualitative Behavior Assessments (QBA and sQBA), a Reactions to a Stationary Human Test (RSH), and a Novel Object Test (NOT). Three observers used the tests to assess the behavior of 12 group-housed calves, alternating in the morning or afternoon (09:30–10:30, 10:30–11:30, 14:00–15:00 and 15:00–16:00) on five consecutive days to evaluate inter-observer reliability and time-dependence. The QBA and sQBA showed indications of low inter-observer reliability, whereas high agreement was observed for the RSH and NOT. Calf activity and behavior were influenced by evaluation time; calves showed higher activity and more test responses between 09:30–10:30 and 14:00–16:00 than 10:30–11:30 in all four tests. *Trichophyton verrucosum* lesions led to higher interactions between calves and observers during the RSH, highlighting the importance of concomitant physiological assessment.

***Keywords:*** self-assessment, welfare indicators, confounding factors, assessment time

## 5.2. Introduction

Assessing animals' mental states is becoming increasingly important as the focus in animal welfare shifts from avoiding negative states to incorporating positive emotions and enhancing quality of life (Boissy et al., 2007). The well-known animal welfare assessment protocol developed by the European Commission's Welfare Quality® Network uses qualitative behavioral assessments (QBAs) to implement positive emotional states (Wemelsfelder et al., 2009). QBAs are conducted based on visual assessments and descriptions of animal behavior, rating terms such as "calm," "tense," or "anxious" on a linear scale (Wemelsfelder et al., 2009). Although female dairy calves have high economic value and young cattle often represent a significant portion of cattle herds, a Welfare Quality® protocol for dairy calves has not been developed (Brscic et al., 2019).

In addition to QBAs, methods to determine fearfulness, such as the Reactions to a Stationary Human Test (RSH) and the Novel Object Test (NOT), have been used in experimental designs to assess single-housed calves; however, such tests have not been applied by farmers under practical conditions (Waiblinger et al., 2006; Forkman et al., 2007; Sant'Anna and Parnhos da Costa, 2013). The RSH assesses animal reactions to a stationary human by measuring the times to first approach and interactions, such as suckling or sniffing. Similarly, the NOT assesses animal reactions when exposed to a new object (Meagher et al., 2016).

Some studies have demonstrated that animals behave differently according to the time of day (Martin and Bateson, 2005). However, time of day has not yet been incorporated into the application of animal welfare behavior tests. Therefore, in this study, we evaluated the reliability and on-farm applicability of a standard QBA, a simplified QBA (sQBA), an RSH, and an NOT at different times of the day

## 5.3. Material and methods

The study was conducted on five consecutive days in January 2020 at the livestock facility of the University of Bonn, Germany. The experimental group consisted of 12 Holstein-Friesian calves between 10 and 90 d old, housed in a deep-bedded straw barn. To assess on-farm applicability, test procedures were performed on the group, not on individual animals as done in previous studies (Waiblinger et al., 2006; Forkman et al., 2007; Sant'Anna and Parnhos da Costa, 2013). The experiment was conducted using a 4 × 4 Latin square design, consisting of four tests (QBA, sQBA, RSH, and NOT) and time periods (09:30–10:30, 10:30–11:30, 14:00–15:00 and 15:00–16:00). The test procedures are described in Supplemental Table S7.7. The three researchers who assessed and analyzed animal behavior were trained using video recordings to ensure a common understanding of the protocols. In addition to the visual assessment, NOT and RSH were recorded using a digital camera and evaluated using BORIS software (Behavioral Observation Research Interactive Software; version 8.0.9, www.boris.unito.it) by the same observers. Descriptive statistics were performed using PROC, FREQ, and MEAN procedures in SAS (Version 9.4, SAS Institute Inc.); data are presented as means with standard deviation. Differences between the three observers and four times were assessed using a Kruskal–Wallis, using the NPAR1WAY procedure. The threshold for significance was set at $P < 0.05$.

## 5.4. Results and discussion

Descriptive results for the QBA and sQBA are shown in Table 5.1. In the RSH and NOT, calves first contacted the stationary human and novel object after 29 s (range: 2–69 s) and 106 s (range: 0–219 s), respectively. Suckling behavior was the most common behavior displayed by calves in both tests, followed by playing/rubbing.

Statistical differences in the assessment results between the observers were detected for the QBA and sQBA (Table 5.1). The deviating behavioral terms were “social,” “positively occupied,” “excited,” “apathetic,” and “irritable” in the QBA and “positively occupied” and “desperate” in the sQBA. No significant differences in assessment results between the observers were detected for the RSH and NOT (neither visual nor video). These findings are consistent with previous studies that reported high inter-observer reliability for NOT and RSH (Bokkers et al., 2009; Meagher et al., 2016), suggesting the relatively simple measurements (e.g., time until contact or duration of contact) reduce disagreements between observers. Lower inter-observer reliability has been reported for the QBA, as the definition and application of behavioral terms, such as “enjoying,” “listless,” and “happy,” are subjective (Czycholl et al., 2016; Bookers et al., 2012). Brscic et al. (2019) proposed that inter-observer reliability could be increased by more extensive training; however, such training requirements would decrease on-farm applicability of tests by farmers.

**Table 5.1.** Means ± standard deviations of a Qualitative Behavior Assessment (QBA) and a simplified Qualitative Behavior Assessment (sQBA) evaluated by three observers (Obs) in 12 group-housed, unweaned dairy calves. Significant differences between observers are indicated by different superscripts ($P < 0.05$).

| Test | Obs 1 (mm) | Obs 2 (mm) | Obs 3 (mm) |
|---|---|---|---|
| QBA | | | |
| Active | 78.0 ± 33.7 | 92.0 ± 18.0 | 79.2 ± 9.9 |
| Agitated | $35.0 \pm 24.2^{b}$ | $24.8 \pm 41.8^{ab}$ | $47.8 \pm 30.3^{a}$ |
| Apathetic | $5.8 \pm 4.4^{a}$ | $1.4 \pm 2.0^{ab}$ | $0.20 \pm 0.5^{b}$ |
| Bored | 25.6 ± 18.9 | 28.8 ± 31.0 | 38.6 ± 5.0 |
| Calm | 84.0 ± 25.9 | 96.0 ± 35.0 | 87.0 ± 14.3 |
| Content | 73.8 ± 18.5 | 78.4 ± 30.3 | 91.8 ± 5.4 |
| Distressed | 6.60 ± 1.3 | 3.4 ± 6.0 | 0.20 ± 0.5 |
| Fearful | 15.0 ± 12.1 | 18.6 ± 23.3 | 25.8 ± 11.8 |
| Friendly | 103.4 ± 4.7 | 64.8 ± 26.4 | 106.0 ± 8.7 |
| Frustrated | 22.8 ± 13.9 | 25.0 ± 30.3 | 39.2 ± 17.2 |
| Happy | 70.8 ± 11.4 | 79.4 ± 25.2 | 80.2 ± 13.2 |
| Indifferent | 18.0 ± 8.5 | 45.8 ± 29.6 | 29.6 ± 14.5 |
| Inquisitive | 80.0 ± 28.3 | 39.8 ± 27.7 | 88.0 ± 15.3 |
| Irritable | $8.0 \pm 3.4^{b}$ | $12.0 \pm 15.7^{ab}$ | $33.6 \pm 13.0^{a}$ |
| Lively | 61.6 ± 39.0 | 38.0 ± 43.8 | 71.2 ± 31.9 |
| Playful | 61.2 ± 45.1 | 37.0 ± 41.4 | 69.2 ± 31.2 |
| Positively occupied | $62.2 \pm 7.7^{b}$ | $85.2 \pm 21.5^{ab}$ | $90.2 \pm 9.0^{a}$ |
| Relaxed | 86.0 ± 28.4 | 92.2 ± 33.8 | 88.0 ± 18.3 |
| Sociable | $104.8 \pm 4.3^{a}$ | $60.2 \pm 25.0^{b}$ | $103.4 \pm 6.5^{ab}$ |
| Uneasy | 18.0 ± 6.8 | 13.8 ± 18.6 | 14.0 ± 7.0 |
| sQBA | | | |
| Active | 72.6 ± 39.7 | 68.2 ± 35.8 | 79.8 ± 23.8 |
| Agitated | 36.2 ± 26.4 | 18.0 ± 20.3 | 44.6 ± 19.2 |
| Apathetic | 4.6 ± 3.1 | 0.6 ± 0.1 | 0.6 ± 0.9 |
| Attentive | 68.4 ± 34.4 | 52.0 ± 36.6 | 75.6 ± 23.7 |
| Calm | 84.6 ± 32.3 | 107.0 ± 13.9 | 87.8 ± 23.4 |
| Curious | 72.0 ± 38.9 | 35.6 ± 27.8 | 81.0 ± 28.0 |
| Distressed | $6.4 \pm 2.9^{a}$ | $1.6 \pm 2.0^{ab}$ | $0.6 \pm 1.3^{b}$ |
| Fearful | 22.2 ± 17.1 | 11.4 ± 11.8 | 16.4 ± 12.9 |
| Happy | 63.8 ± 15.6 | 74.0 ± 24.4 | 80.8 ± 16.1 |
| Irritable | 5.2 ± 1.5 | 4.4 ± 6.1 | 22.0 ± 18.5 |
| Positively occupied | $53.2 \pm 5.6^{b}$ | $67.6 \pm 14.4^{ab}$ | $81.2 \pm 7.9^{a}$ |
| Relaxed | 86.4 ± 27.6 | 89.0 ± 16.6 | 87.0 ± 21.5 |

Different degrees of activity were observed; the time from 10:30–11:30 was defined as the resting phase (max one-third of calves standing), and 09:30–10:30 and 14:00–16:00 were defined as active phases (min two-thirds of calves standing).

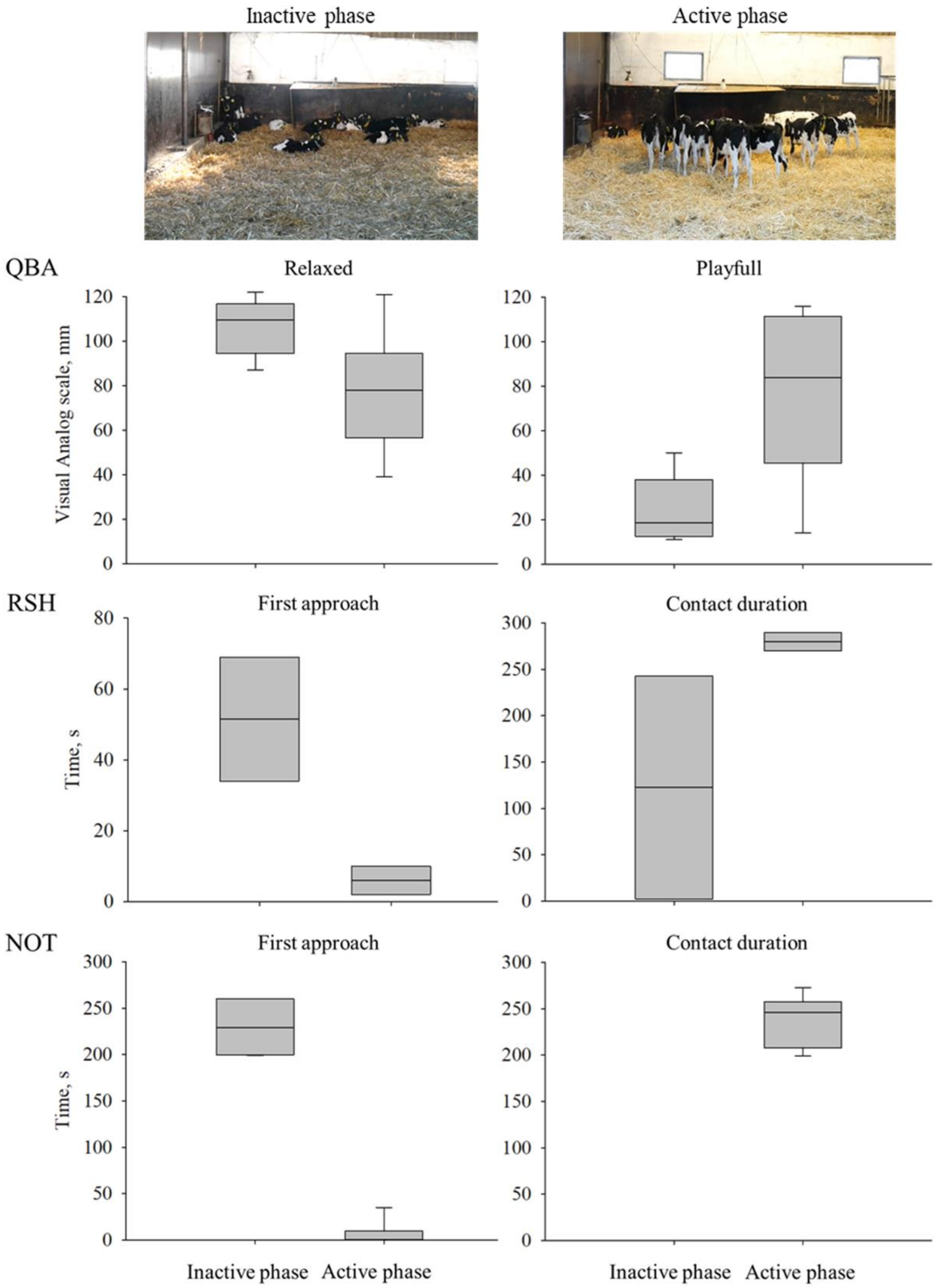


**Figure 5.1.** Significant differences ($P < 0.05$) among selected parameters of a Qualitative Behavior Assessment (QBA), a Reaction to Stationary Human test (RSH), and a Novel Object Test (NOT), according to the time of the assessment (inactive phase, 10:30–11:30; active phases 09:30–10:30 and 14:00–16:00; representative photographs are shown in the top panels) in 12 group-housed, unweaned dairy calves.

The QBA analysis showed that the terms “active,” “playful,” and “lively” were rated significantly higher during the active phase, whereas “relaxed” and “calm” were rated lower. The descriptors “fearful” and “inquisitive” also tended to be rated higher during the active phase. The sQBA mirrored these results, with higher ratings for “active,” “agitated,” “inquisitive,” “attentive,” and “fearful” and lower ratings for “calm” and “relaxed” during the active phase. In the RSH and NOT, the time until first contact and duration of contact were significantly lower during the active phase (Figure 5.1). Accordingly, most calves only showed playing, suckling, and avoidance behaviors in the RSH (average 5.7, 2.5, and 3.7 calves, respectively) and NOT (average 1.5, 1.8, and 0.5 calves, respectively) during the active phase. Gutman et al. (2015) analyzed the intra-day variation of QBA outcomes at three observation times (08:00, 11:00, and 13:00) in dairy cows and found that activity patterns differed on eight of ten assessed farms. The highest activity was observed in the early morning, followed by the afternoon, whereas activity was significantly reduced in the late morning. Thus, they recommended multiple assessments per day for comprehensive evaluations and a standardized assessment time for comparing single assessments between farms. As dairy calf management and housing differ greatly between farms (Hayer et al.,2021), we suggest scheduling assessments based on the number of active or standing calves (e.g., two-thirds of the group) rather than a specific time. However, more research is needed to analyze the specific diurnal behavior of calves between farms.

Time, financial requirements, and ease of integration into daily workflows should be considered when developing or assessing test procedures (Napolitano et al., 2009; Mattiello et al., 2019). We evaluated on-farm applicability using items in four categories: time, number of staff, materials, and training required (Supplemental Table S7.7). The QBA was the most time-consuming procedure (20 min per group). The time required for the sQBA was lower, as the observation time per calf was limited to 30 s (e.g., 7.5 min for 15 calves). The sQBA might be suitable for farms with fewer calves per group and more groups. For video recording and analysis of the RSH and NOT, a camera, software, and basic technical understanding are required. The video recording method did not improve test reliability but can reduce the personnel requirements from two to one. Overall, the sQBA and NOT appear to be the most applicable on-farm methods for evaluating calf groups. However, the validity of behavioral tests is still in discussion, and reliability and applicability are only two of the multiple requirements to consider (Meagher et al., 2016).

Lethargy and decreased exploratory behavior are typical indicators of sickness (Meagher et al., 2016), and calves with respiratory illness and fever have been reported to approach novel

objects and stationary humans less often than healthy calves (Cramer and Stanton, 2015). In this study, some calves suffered from visible lesions caused by *Trichophyton verrucosum*, which negatively affected their welfare. During the RSH, we observed infected calves rubbing themselves against the stationary human. Rubbing is classified as a positive behavior according to the test (Krohn et al., 2003) but was associated with an animal health impairment in this instance. To better interpret animal behavior, physiological states should also be assessed. Furthermore, calves in this study were fed with an automatic feeder and had constant access to milk. Calf behavior is highly influenced by milk allowance and feeding practices (Jensen et al., 2015); thus, evaluating these tests on farms with manual feeding systems may produce different results. Additional influential factors might be group size (Lensink et al., 2001), available space (Jensen et al., 1998), housing design, or temporary external factors, such as the recent addition of fresh bedding (Pempek et al., 2017). To accurately evaluate inter-observer reliability and retest reliability (Czycholl et al., 2016), multiple groups of calves should be assessed. However, medium-sized facilities typically only have one calf group per age, making multiple group assessments unfeasible. Moreover, inter-farm effects are highly influential, preventing accurate comparisons of calf groups at different farms (Brscic et al., 2019).
In conclusion, the four tests differed in terms of time and effort required but were all feasible. Both QBA versions show indications of reduced inter-observer reliability in contrast to the NOT and RSH. Farm-specific rest and activity times should be considered when testing, as daily rhythms significantly influenced calf behavior. Further research is required to enhance the on-farm applicability of dairy calf behavioral tests.

## 5.5. Ethics approval

We conducted this study in accordance with ethical standards, the data privacy agreement of the University of Bonn (University of Bonn, 38/2018), and federal and institutional animal use guidelines (FF AZ 01K 1901 201912).

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# 6. General discussion and conclusion

## 6.1. General discussion

Animal welfare is a complex, multidimensional concept, which changes with developments in societies. The interest of society and science on the welfare of farm animals is increasing, and demands for improved animal welfare of livestock are raised (von Keyserlingk et al., 2017). To directly improve farm animal welfare, three main approaches were outlined: more comprehensive animal welfare regulation, animal welfare labels and consumer choice, and farmer-driven initiatives to improve the welfare of livestock (Christensen et al., 2019). Ultimately, farmers have the most significant impact on the welfare of animals as they put legal regulations into practice, apply and implement measures of animal welfare labels, or take the initiative to provide their animals a good life. Furthermore, farmers are emotionally connected to the animals they keep and value their welfare from an ethical standpoint (McInerney, 2004; Lagerkvist et al., 2011; Hansson et al., 2018). Identifying farmers' reasons and motivation for implementing animal welfare regulations and recommendations is thus key to facilitate improvements in animal welfare on farms.

The presented studies aimed to assess the implementation of scientific recommendations in calf management on Western German dairy farms, evaluate farmers' perceived responsibility and their view towards animal welfare, and identify challenges associated with animal welfare regulations and recommendations (chapter 2). In 1998, the EU laid down minimum standards for animal welfare, which have been incorporated into German regulation in a more detailed and stringent manner. Accordingly, German animal welfare regulations are considered particularly comprehensive in a European and worldwide comparison (Vogeler, 2019). Nevertheless, to provide animals a "life worth living," full compliance with enacted animal welfare regulations is required (FAWC, 2009). The survey presented in chapter 2 revealed that only 26.2% of surveyed farms complied with all nine evaluated calf rearing management regulations. Sedation for disbudding, feeding of calves at least twice a day, and group housing from day 56 onwards were the only regulations implemented on all farms surveyed. Especially, access to solid feed from day 8 and to water from day 14 as well as tactile contact between calves were frequently violated regulations. Therefore, it can be assumed that only enacting stricter animal welfare regulation is no sustainable approach to improve cows' and calves' welfare. Firstly, already existing legal requirements have to be fully implemented on dairy farms. Consequently, transparent and frequent controls must be performed to identify non-compliance and ensure improvements by follow-up controls (Lomellini-Dereclenne et al., 2017; Lundmark Hedman et al., 2018). Member states of the EU are legally required to conduct controls for compliance with animal welfare regulations. However, the member states determine the frequency; for example, 1% of all French farms and 10% of all Swedish farms are inspected per year (Lomellini-Dereclenne et al., 2017; Lundmark Hedman et al., 2018). In Germany, the federal states organize controls, which leads to considerable variations between the individual states. On average, every livestock farm is controlled every 7.3 to 48.1 yrs, excluding city-states (Deutscher Bundestag, 2018). Farms in Rhineland-Palatinate and North Rhine-Westphalia, the regions of the farms investigated as part of this thesis, were controlled on average every 15.5 yrs and 14.7 yrs, respectively (Deutscher Bundestag, 2018). It is also important to emphasize that these inspections are risk-based, with criteria specified by Regulation (EU) No 2017/625 (Deutscher Bundestag, 2018). Named criteria for risk assessments are, for example, operators' past record of official controls or the reliability and results of own controls by farmers or by a third party (EU, 2017). Even though the farms surveyed in this thesis were not evaluated and selected based on these risk criteria, they were chosen to represent average farms. Furthermore, the farms most likely have a low-risk profile because they voluntarily participated in the study. Nevertheless, many legal regulations were not implemented on these farms. Identifying additional science-based criteria for animal welfare controls could be an approach to better monitor these farms. In addition to the revision of official control schemes, developing an officially accepted and regularly updated guideline for keeping dairy cows and calves could specify vague animal welfare regulations and help farmers comply with legal regulations.

Legal regulations generally promote animal welfare but also directly impair animal welfare by mandating the identification of newborn calves within the first 7 d p.p. by ear tags in both ears (BMJV, 2007). This procedure is associated with pain and causes wound lesions (chapter 3). Still, identification of animals is essential to ensure traceability along the agri-food chain or combat epizootic diseases (Schroeder and Tonsor, 2012). If an animal's whole life was considered from a "quality of life" point of view, identification might also lead to an improvement of overall animal welfare. Nevertheless, ear-tagged calves suffer from the pain caused by the procedure and the associated impairments. The recommendations and risk factors identified in this thesis can be used to improve ear tagging management or lower the risk of adverse effects of ear tagging (chapter 3).

All animal welfare regulations, current recommendations, and standards have to be complied with to provide animals a “good life” (FAWC, 2009). Several surveys investigated dairy calf management in countries such as Austria (Klein-Jöbstl et al., 2015), Brazil (Hötzel et al., 2014), Canada (Renaud et al., 2017), Czech Republic (Staněk et al., 2014), Ireland (Barry et al., 2020), Norway (Johnsen et al., 2021), or the United States (Urie et al., 2018). By comparing different international dairy calf management surveys, Mee (2020) showed that many management recommendations were implemented only on a minority of dairy herds internationally (e.g., hygiene in calving pens, measuring colostrum quality, cow-calf separation, or umbilical disinfection). However, data on calf management on German dairy farms was missing until recently. The survey described in chapter 2 revealed that poor calf management is not only an international issue but also concerns German dairy farms. Out of 52 scientific management recommendations, on average, only 56.3% were implemented on the farms surveyed. The farmers' decision to implement management recommendations is influenced by socio-psychological factors such as "farmers characteristics," "perceived abilities to make changes," "benefits and disadvantages of recommendations," "problem awareness and perceived responsibility," and "effectiveness of proposed changes"(Ritter et al., 2017). All factors except "farmers characteristics" can be altered to encourage farmers to implement recommendations and thereby improve dairy calf welfare. One key aspect of increasing farmers' perceived ability to implement recommendations is to provide them with sufficient knowledge on the necessity of implementing the recommendation and how to accomplish the task (Ritter et al., 2017). Recommendations are still needed for some animal welfare aspects such as ear tagging, the movement of calves on the farm, or the removal of supernumerary teats (chapter 3), whereas other aspects such as colostrum management or milk allowance are well explored (chapter 1.3.1). To provide farmers with animal welfare recommendations and guidelines, the "Dairy Farmers of Canada" and the "National Farm Animal Care Council" published the "Code of Practice for the Care and Handling of Dairy Cattle" in 2009, which represents a comprehensive science-based handbook for best practice in dairy husbandry for Canadian dairy farmers (DFC-NFACC, 2009). In a survey representing 9% (n = 1,025 farms) of all Canadian dairy farms, 82% of respondents stated to be aware of the code, and 22% used it frequently (Renaud et al., 2017; Winder et al., 2018a). Moreover, this guide seems to be an effective tool for knowledge transfer, as farmers who have consulted the code implemented management recommendations such as ensuring the uptake of a sufficient amount of high-quality colostrum, navel dipping, or avoiding the use of blunt force trauma on bull calves more often (Renaud et al., 2017; Winder et al., 2018a). However, an equivalent to the Canadian code of practice for German dairy husbandry is missing, and a simple transfer of the Canadian code is not possible due to legal and geographical differences between the countries. The development of an animal welfare code of best practices on German dairy farms could increase farmers' knowledge of animal welfare and increase the implementation rate of management recommendations.

Nevertheless, knowledge of best practices alone does not guarantee their implementation, as shown by Heinemann et al. (2021). They investigated hygiene management of single housed calves and found that farmers were aware of best hygiene practices but did not implement them despite the training provided and the high bacterial load found. Underlying reasons for low implementation rates identified in this thesis (chapter 2) and other studies are the shortage of workforce and the enormous workload in dairy farming, exacerbated by an increasing number of animals – and especially calves – held per farm (Vaarst and Sørensen, 2009; Kallioniemi et al., 2016). In an unpublished survey on the wellbeing of German livestock farmers (n = 116) conducted in 2021, the median workload was 60 h/week. Furthermore, 76.7% of farmers surveyed stated to work every day of the week, and 68.3% claimed to work even if they are sick or physically at their limit (Reusch, 2021). The relationship of farmers' workload, their own wellbeing, and animal welfare has been discussed in chapter 2 and was reflected in statements of the farmers surveyed in this survey: "*I think it is especially important to state that I am not able to take care for my animals the way they demand it due to my own stress, which in turn puts psychological strain on me.*" In addition to the workload, several recommendations, such as administrating local anesthesia for disbudding, require additional economic expenses that often do not result in additional direct economic returns.

Besides ensuring animal welfare and their own wellbeing, farmers are also expected to reduce the emissions caused, the use of pesticides, or the development of antibiotic-resistant bacteria, while producing safe, high-quality food. The relationship between the different goals, by contrast, has not been adequately researched yet. For example, recent research has shown that antibiotic-resistant bacteria are prevalent in dairy calves on many German dairy farms (Hayer et al., 2020; Waade et al., 2021). On the one hand, measures to improve animal welfare such as avoiding the feeding of waste milk, good hygiene in calf housing and calving pens, or vaccinating calves have been found to reduce the prevalence of antibiotic-resistant bacteria (Aust et al., 2013; Maynou et al., 2017; Kahn et al., 2019; Formenti et al., 2021). On the other hand, increased social contact and group housing have been discussed to promote antibiotic-resistant bacteria in calves (Duse et al., 2015). Limiting the use of antibiotic treatments, which is highly effective in lowering the prevalence of antibiotic-resistant bacteria (Afema et al., 2019), had no direct effect on diarrhea incidence and mortality of calves (Bokma et al., 2019; Gomez et al., 2021). However, treatment restrictions have also been discussed to lower animal welfare, as alternative treatments are not as effective and might lead to the unnecessary suffering of sick animals (Karavolias et al., 2018; Broom, 2019). For most measures to improve animal welfare, it is uncertain how they affect other sustainability goals in dairy calf husbandry. In order to sustainably enhance animal welfare, the effect of management measures on associated objectives such as the reduction of antibiotic-resistant bacteria, farmers' wellbeing, or environmental protection should be simultaneously assessed (Hansen and Østerås, 2019). The multidimensional and multidisciplinary "One Welfare"-concept provides a framework for a sustainable improvement (Pinillos et al., 2016).

Another precondition for farmers to take action is that they believe in the importance of proposed changes and feel responsible, referring to aspects of "problem awareness and perceived responsibility" (Ritter et al., 2017). The results obtained in chapter 2 and other publications indicate that farmers who consider animal welfare to be important and who can empathize with animals, handle them better, implement more management recommendations, and had better ratings of animal welfare indicators assessed on their respective farms (Lensink et al., 2000; Munoz et al., 2019; Albernaz-Gonçalves et al., 2021). In addition to the recognition of animal welfare being an essential factor, it is necessary to understand farmers' definition of animal welfare and their values (Fraser, 2003, 2008). Farmers surveyed in the course of this thesis and other studies defined animal welfare mainly by the provision of specific provisions such as water, feed, or space and production traits such as health or growth (Figure 2.4) (Benard and Cock Buning, 2013; Albernaz-Gonçalves et al., 2021). Similarly, studies have shown that farmers often focus on single criteria to evaluate the overall welfare of their animals (e.g., low mortality, good health, or sufficient space) while being "blind" to other aspects (Mee, 2020; Albernaz-Gonçalves et al., 2021; Heinemann et al., 2021; Veissier et al., 2021). The view of farmers on animal welfare is further limited by a phenomenon described as "barn-blindness." It describes farmers normalizing poor calf management and welfare by keeping no or insufficient records, underestimating the problem, being unable to make changes, or being desensitized to the problem (Mee, 2020). This phenomenon was also partly visible in the conducted survey, as nearly every stockman described the welfare of the calves kept as high, although they did not implement many recommendations (chapter 2). This low sensitivity was observed not only in calf management in general but also in the adverse effects of ear tagging. Most farmers interviewed in the study described in chapter 3 were unaware of wound lesions frequently impairing animal welfare. One method to raise awareness of all areas of animal welfare, to address less prominent issues, and to demonstrate the potential benefits of implementing animal welfare recommendations is to assess and evaluate animal welfare using resource- and animal-based indicators in addition to management-based indicators. Self-assessments by farmers themselves can have an additional benefit because farmers observe and evaluate animal welfare indicators personally, thus increasing their empathy and sense of responsibility for their animals (Zapf et al., 2017).

According to the German Animal Welfare Act § 11 Section 8, farmers are obligated to assess the welfare of their animals by reliable, animal-based indicators (BMJV, 1972). However, no specifications on the implementation of the required assessments or the indicators needed are available. In addition, current animal welfare assessments miss protocols for dairy calves in general (Welfare Quality® project (Welfare Quality®, 2009) or essential animal welfare aspects due to their choice of indicator categories (QM-Milch (Flint et al. (2016) and KTBL (Brinkmann et al., 2016)). According to the legal requirement, the assessment must include animal-based indicators. The KTBL protocol, which attempted to incorporate the regulation, is thus based exclusively on animal-based indicators. However, assessments that focus on animal-based indicators only cannot provide information on the cause of the outcome of the assessment (Barry et al., 2019). In order to initiate corrective measures in case of impaired animal welfare, measurable by animal-based indicators, the simultaneous assessment of input factors such as resource- and management-based indicators is required. Furthermore, not for every animal welfare aspect evaluated, valid and feasible animal-based indicators are currently available. The example of evaluating the provision of free water using animal-based indicators (Kells et al., 2020) has already been discussed in chapter 1.4.1. Another example is assessing pain caused by disbudding, which is currently mainly evaluated by assessing the management of disbudding and the medication administered. Animal-based indicators such as ear flicking, head shaking, foot-stamping, or vocalization have already been proposed for evaluating pain during disbudding (Winder et al., 2018b). However, these are mainly assessed during the procedure, which is challenging to implement for self-assessment by farmers, as farmers usually perform the procedure themselves and are therefore unable to perform an assessment simultaneously. In another study recently conducted by the University of Bonn, feasible animal-based indicators for disbudding are evaluated for on-farm self-assessments. An initial analysis showed that disbudded calves exhibited significantly more head and ear shaking during the first milk meal after disbudding (Steegmann, 2020) – both behavioral parameters have already been associated with pain (Sylvester et al., 2004; Heinrich et al., 2010; Winder et al., 2018b). In addition, the frequency of head and ear shaking was decreased when a pain-relieving topical ice spray was applied before disbudding compared to cauterization without using an ice spray. Assessing calf behavior during feeding following disbudding could be a viable alternative to management-based indicators to evaluate pain mitigation measures. However, until those indicators are validated in the field, management-based indicators will remain valuable to consider the animal welfare issues described.

Additionally, resource- and animal-based indicators need to be reliable in order to be used in welfare assessments (Scott et al., 2003). Reliability consists of inter-observer reliability, intra-observer reliability, and consistency over time, which might be affected by influencing factors (chapter 1.4.). Dairy calves, in particular, are fast-growing animals that undergo significant changes in the first weeks of life and are kept under heterogeneous conditions. Therefore, the factors influencing the results of the animal welfare indicators used must be identified to interpret these indicators and facilitate their use for management decisions (Mason and Mendl, 1993). Hence, part of this thesis was to evaluate potential resource- and animal-based indicators for their on-farm applicability and to evaluate the impact of influential factors on the assessment's outcome (chapter 4). Furthermore, four different behavioral tests were evaluated for their on-farm applicability and inter- and intra- observer reliability (chapter 5). Only one of the 21 resource- and animal-based indicators applied in chapter 4 was independent of the influential factors evaluated. Especially the parameter calf age influenced the outcome of the assessment and varied from farm to farm. A comparison of the assessments' results between farms or a threshold should be carefully reconsidered, or the results should be adjusted to the effect of influencing factors beforehand. Furthermore, the evaluation of calf behavior to assess the human-animal relationship and animal's mental state revealed that the recorded behavior was partly influenced by the physical conditions of the animals assessed. Several calves suffered from lesions associated with *Trichophyton verrucosum,* which induced rubbing behavior that is usually considered positive. Also, approach probability in the Novel Object Test, which is used as an indicator for the fear of humans, is lower when calves suffer from respiratory disease (Cramer and Stanton, 2015). Both studies demonstrate that calves' behavior is influenced by their physical condition and that a coherent interpretation of recorded behavior is only possible if the physical state is evaluated simultaneously.

In order to motivate farmers to assess the welfare of their calves regularly and trust the indicators used, these indicators must assess consistent traits in animals (Scott et al., 2003). Providing farmers with information on how their obtained results are influenced could increase their trust in the assessed animal welfare indicators. The knowledge about influencing factors could be used either to adjust single indicators or the entire assessment to the effects (e.g., seasonal measurements or assessment of calves of a certain age) or to better interpret the assessment's results. Inter- and intra-observer reliability is also key to a reliable assessment of animal welfare. However, both studies conducted on animal-based indicators in this thesis and other publications indicate that individual observers rate indicators differently and that repeated measurements can produce different results (Plesch et al., 2010; Czycholl et al., 2016; Czycholl et al., 2019; Pfeifer et al., 2019). For the indicators evaluated in chapter 4, comprehensive estimations of inter- and intra-observer reliability are currently missing. Accordingly, the evaluation of both criteria is the aim of a currently written master thesis at the University of Bonn.

Animal-based and especially behavioral indicators are more difficult to measure and often lack reliability. Nevertheless, the mental state of animals is the most crucial animal welfare domain and should therefore be given greater focus in welfare assessment (Mellor, 2016; Veasey, 2017; Rault et al., 2020). Vaarst and Sørensen (2009) described this reasoning as the "need to prioritize the meaningful over the measurable" to achieve peak animal welfare. In addition, participating farmers considered behavioral indicators such as "curiosity" or "playing behavior" as valuable for animal welfare assessments in calves as well (chapter 2). Training in assessing animals' behavior has been discussed as an approach to increase inter-observer reliability of animal welfare self-assessments (Pfeifer et al. 2019). It could enable farmers to derive valuable and more reliable information on the welfare of their calves. However, additional training would result in additional expenditures for assessments and, thus, lower feasibility. Regardless of the assessment's reliability, the evaluation by farmers themselves may focus their attention on animal welfare, increase their problem awareness and perceived responsibility, or make them challenge their current husbandry system through the process of the assessment itself (Zapf et al., 2017; Pfeifer et al., 2019). Nonetheless, the question remains as to whether farmers are willing to conduct animal welfare self-assessments. Although the assessment is legally required, it is not sufficiently specified, and there are currently few controls of the implementation and few consequences in case of non-compliance. Additional paperwork and administrative workload caused by government regulations have been identified as significant stressors for farmers in developed countries (Daghagh Yazd et al., 2019). Furthermore, 85.7% of farmers surveyed in a study on the wellbeing of farmers in Germany indicated that they are highly stressed by increasing paperwork (Reusch, 2021). Consequently, enforcing the regulation through regular documentation checks alone will likely lead to increased stress and compromise farmers' wellbeing. For a successful implementation, farmers must be convinced by an assessment that is feasible, can assess animal welfare effectively, and includes indicators that farmers accept. Pfeifer et al. (2020) questioned pig farmers on the feasibility and acceptance of indicators included in the KTBL assessment for pigs. They found that farmers disagreed with the importance of certain indicators (e.g., tail length or soiling), that they would like to add additional indicators, and perceived the assessment as inefficient. One possible solution to resolve this matter could be the creation of an indicator toolbox to be regularly updated with indicators suggested by farmers and researchers. Farmers could influence the selection of indicators for the individual assessments while being encouraged to assess new ones. It could be a tool of animal welfare monitoring in general, assist in identifying previously unrecognized animal welfare impairments, and provide information on the impact of newly implemented management measures. By doing so, assessments would not be limited to certain indicators, farmers would feel more included and recognized as professionals, and new research could be implemented directly into practice. However, as there is no such system as of now, it would first need to be created and evaluated.

Precision livestock farming represents another approach to improving animal welfare and calf management in general. Technological applications have been discussed to monitor husbandry conditions (e.g., climatic conditions), detect early signs of illness, evaluate animal behavior, or improve data management on-farm (Wurtz et al., 2019; Buller et al., 2020; Stygar et al., 2021). The challenges highlighted in this thesis could also be addressed by applying technical solutions. For example, the implementation of automatic milk feeding techniques on dairy farms could address some management challenges identified in chapter 2 by reducing the workload associated with calf feeding, facilitating the implementation of gradual weaning strategies, and providing essential data for early disease detection (Costa et al., 2021). Furthermore, in a study conducted in Canada, Medrano-Galarza et al. (2017) found that farms with an automated milk feeder fed more milk, housed their calves in groups more often, and implemented more automation in general than farms with manual milk feeding systems. Referring to chapter 3, ear tagging and a discussion of associated adverse effects would be obsolete if feasible and reliable non-invasive methods of identification were available. Non-invasive identifiers such as muzzle prints (Noviyanto and Arymurthy, 2013; Awad and Hassaballah, 2016) and iris patterns (Lu et al., 2014) have been researched; however, these identification methods need to be validated and tested under practical conditions first (Awad, 2016). In order to account for influencing factors identified in chapter 5, environmental conditions could be monitored by weather sensors and evaluated along with other influencing factors through machine learning approaches. However, large data sets would be required to do so. Smart technologies could improve not only the reliability of the assessment but also its feasibility. For example, farmers interviewed by Pfeifer et al. (2020) regarding the feasibility of the KTBL self-assessment protocol for pigs stated to prefer a digital application for the assessment that automatically performs the analysis. Researchers have even advocated conducting animal welfare assessments such as the Welfare Quality® Protocol for cattle by using precision livestock management concepts rather than human observations (Buller et al., 2020; Stygar et al., 2021). Validated precision livestock technologies would have the advantage of being more standardized, reliable and would allow a continuous (whole-life) animal welfare assessment (Buller et al., 2020). However, it seems questionable whether measuring animal welfare in the context of self-assessments has the same effect on farmers' problem awareness and perceived responsibility as personal observation of individual animals. Reviews on the ethical implications of precision livestock farming raise concerns that it may lead to a more distanced relationship between farmers and livestock and an objectification of the animals held (Bos et al., 2018; Werkheiser, 2018). In a survey among European consumers, these concerns were also expressed, although the potential benefits of technology for the farmer and animal welfare were acknowledged as well (Krampe et al., 2021). Further studies are needed to address the questions and concerns raised about the farmer-animal relationship.

Another ethical problem identified in this thesis and other studies was the differentiation between calves of different sexes and the mistreatment of bull calves. Bull calves received less milk and more often waste milk or milk with high SCC (chapter 2), were ear-tagged differently (chapter 3), and were at higher risks for being scored as runts and having a navel inflammation than heifer calves (chapter 4). This aspect is also reflected in international studies, which have shown that bull calves were fed less colostrum that is provided later or only by suckling from the dam (Renaud et al., 2017; Shivley et al., 2019), fed less milk (Renaud et al., 2017), and more often received waste milk (Klein-Jöbstl et al., 2015). Bull calves also had a higher risk for dystocia and higher overall mortalities (Lombard et al., 2007; Raboisson et al., 2013). In addition, bull calves experience pain more often as they are commonly castrated in special fattening husbandries (Hötzel et al., 2014; Shivley et al., 2019) or are disbudded more often with unrecommended techniques than female calves (Shivley et al., 2019). Especially concerning are reports of cullings of male calves by blunt force on-farm due to their low profitability (Hötzel et al., 2014; Renaud et al., 2017). Bull calves in Germany are often sold to bull or veal fattening farms at two weeks of age rather than reared on-farm (chapter 2). The transportation of animals and especially young calves, which are most susceptible to infections at two weeks of age due to the occurring immune gap, is a stressful experience (Hulbert and Moisá, 2016; Roadknight et al., 2021). In response to public criticism, the German government and Federal Council passed a revision of the Ordinance on the Protection of Animals during Transport on the 25$^{th}$ of June 2021 (BMJV, 2009), which states that calves may only be transported if they are at least 28 d old instead of 14 d. It is unclear how the amended regulation will affect the management of bull calves, which now have to be reared on dairy farms for two additional weeks. The fundamental cause for the differentiation between male and female dairy calves is the ongoing specialization and breeding toward one-purpose dairy breeds (e.g., Jersey, Holstein-Friesian, or Brown Swiss). Surplus female and male dairy calves, which are unfit or unsuitable for dairy production, are mostly fattened as veal calves instead of undergoing conventional cattle fattening due to their genetically determined lower average daily gain and less desirable carcass composition in comparison to specialized beef breeds (Albertí et al., 2008; Hayer et al., 2018; Bolton and Keyserlingk, 2021). The limited suitability of dairy calves for fattening affects their market value negatively and consequently lowers dairy farmers' attention (Bolton and Keyserlingk, 2021). For example, the market price for two-week-old male Holstein calves in West Germany has continued to decline over the past two decades, reaching a historic low of 25 € in May 2020 (Föster, 2021). Furthermore, cases of symbolic prices of 1 € per calf or even charges for transporting calves off the dairy farm have been reported (Föster, 2021). From an ethical standpoint, the creation of unwanted life and the mistreatment of bull calves in today's dairy industry are major concerns (Franco et al., 2014; Hayer et al., 2018; Haskell, 2020). Young animals, in particular, are the subject of emotional attention by consumers, and animal welfare impairments in young animals receive special attention from society and government (Franco et al., 2014; Hayer et al., 2018). Although the dairy industry in Germany is less criticized than other livestock sectors regarding animal welfare, the ban on piglet castration without anesthesia and the ban of killing day-old chicks underlines the German society's ethical stance on the issue. Therefore, the dairy industry must adapt to ensure animal welfare for surplus calves as well and thus create a sustainable future (Hayer et al., 2018; Haskell, 2020; Bolton and Keyserlingk, 2021). The Canadian code of practice addresses this issue directly by stating that the code applies to all dairy cattle, including bull calves; however, the mistreatment of bull calves has also been observed in Canada (Renaud et al., 2017). Approaches to initiate change and to improve the welfare of surplus calves have been described in detail elsewhere (Hayer et al., 2018; Haskell, 2020; Bolton and Keyserlingk, 2021; Föster, 2021). They include crossbreeding with beef cattle, implementing new marketing labels ("brother-calf-initiatives"), rearing calves with cows, or raising them regionally.

## 6.2. Conclusion

In conclusion, ensuring the welfare of dairy calves is an essential foundation for sustainable dairy farming, and farmers can highly influence this through their decision-making. In this thesis, the status quo of calf management on West German farms, associated challenges, and farmers' perception of animal welfare have been assessed. Furthermore, ear tagging was identified as a routine management procedure that causes distress and pain, not only during the procedure but also due to the development of lesions. Combined with derived management recommendations, the outlined findings can raise awareness for this issue and improve animal welfare. Self-assessments, including animal-based indicators, are currently discussed as an effective tool for assessing the welfare of animals, identifying risks, and raising awareness for animal welfare. The proposed indicators for a self-assessment of calf welfare, the identified influencing factors, and the evaluation of behavioral assessments provide additional elements leading to a feasible and reliable system for assessing calf welfare by farmers. However, the knowledge and the existing recommendations must be successfully transferred to farmers to improve calf welfare. Further research on animal welfare self-assessments is required to refine and evaluate the assessment regarding feasibility, reliability, and validity.

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# 7. Appendix

## 7.1. Supplemental material for chapter 2

**Supplemental Table S7.1.** Areas of interest and parameters of the structured guided interview on calf management and attitude towards animal welfare of the stockperson in Western German dairy farms, including the on farm-recording method (qualitative nominal question (QN), qualitative ordinal question (QO), continuous question (C), open question (O), numerical scale question (NS) and visual assessment (VA)) and management recommendations used for comparison.

| Area of interest | Variable | Method of recording[1] | Used recommendations | Source of recommendation |
|---|---|---|---|---|
| (1) Farm Characteristics | | | | |
| | Sex of the respondent | QN | | |
| | Age of the respondent | C | | |
| | Education level of the respondent | QO | | |
| | Participation of the respondent in animal welfare training | QN | | |
| | Herd size | C | | |
| | Used breed | QN | | |
| | Responsibility for calf management | O | | |
| | Regular treatment by veterinarian | QN | | |
| | Regular consultancy by a veterinarian in calf rearing | QN | | |
| | Regular consultancy by a consultant in calf rearing | QN | | |
| | Mortality 14 d pp. | C | | |
| | Mortality until weaning | C | | |
| | Diarrhea incidence | C | | |
| | Respiratory disease incidence | C | | |
| | Dystocia incidence | C | | |
| | Analysis of feces samples | O | | |

| Area of interest | Variable | Method of recording[1] | Used recommendations | Source of recommendation |
|---|---|---|---|---|
| (2) Calving management | | | | |
| | Use of calving pens | QN | Calving should be possible in a separated calving pen | Waltner-Toews et al. (1986), Gulliksen et al. (2009), Torsein et al. (2011), Pithua et al. (2013), Donat et al. (2016) |
| | Number of cows per calving pen | C | | |
| | Calving pen used as hospital pen | QN | Calving pens should not be used for housing sick cows | McKenna et al. (2006), Vasseur et al. (2010), Donat et al. (2016) |
| | Bedding material | O | | |
| | Cleaning method | O | Calving pens should be cleaned with additional cleaning measures than just re bedding | McKenna et al. (2006), Collins et al. (2010), Donat et al. (2016), Klein-Jöbstl et al. (2014) |
| | Cleaning interval | O | Calving pens should be cleaned after every calving or at least every 4 weeks | Frank and Kaneene (1993), McKenna et al. (2006), Klein-Jöbstl et al. (2014), Donat et al. (2016) |
| | Disinfection of calving pens | O | Calving pens should be disinfected | McKenna et al. (2006); Donat et al. (2016) |
| | Disinfection interval | O | Calving pens should be disinfected after every use | McKenna et al. (2006); Donat et al. (2016) |
| | Usage of mechanical calf puller | QN | Mechanical calf puller should only be used if necessary | Schuh and Killeen (1988), Pearson et al., (2020), Lange et al. (2019) |
| | Dystocia documentation | QN | Occurrence of dystocia should be documented | Nordlund and Cook (2004), Villettaz Robichaud et al. (2016) |
| | Separation of calf from dam during day calving | QO | Calves should be separated 1 – 4 h p.p. | Gulliksen et al. (2009), Donat et al. (2016), Godden et al. (2019) |
| | Separation of calf from dam during night calving | QO | Calves should be separated 1 – 4 h p.p. | Gulliksen et al. (2009), Donat et al. (2016), Godden et al. (2019) |
| (3) Colostrum management | | | | |
| | Measures to control the intake of colostrum | QN | Colostrum intake should be checked either visually or by feeding colostrum | Wesselink et al. (1999), Godden et al. (2019), Johnsen et al. (2019) |
| | Time of first meal | QO | First colostrum meal should be fed in the first 1 – 6 h p.p. | Stott et al. (1979), Fischer et al. (2018), Godden et al. (2019) |

| Area of interest | Variable | Method of recording[1] | Used recommendations | Source of recommendation |
|---|---|---|---|---|
| (3) Colostrum management | | | | |
| | Checking colostrum quality | QN | Colostrum quality should be checked | Vasseur et al. (2010), Buczinski and Vandeweerd (2016), Shivley et al. (2018), Godden et al. (2019) |
| | Amount of colostrum fed | O | At least 3 L should be fed in the first 12 h p.p. | Faber et al. (2005), Morin et al. (2001), Godden et al. (2019) |
| | Colostrum feeding method | QN | Suckling the dam as the colostrum feeding method should be avoided; nipple bottle preferred, esophageal tube feeder if needed | Edwards and Broom (1979), Svensson et al. (2003), Gulliksen et al. (2009), Desjardins-Morrissette et al. (2018), Godden et al. (2019) |
| | Using colostrum of first parity cows | QN | | |
| | Having a stock of colostrum | QN | A stock of frozen colostrum should be stored | Staněk et al. (2014), Cummins et al. (2017), Godden et al. (2019) |
| (4) Housing and transport | | | | |
| | Navel disinfection | QN | Navel of newborn calves should be disinfected | Grover and Godden (2010), Jorgensen et al. (2017) |
| | Time of navel disinfection | QO | Navels should be disinfected as soon as possible after birth | Grover and Godden (2010), Jorgensen et al. (2017) |
| | Single housing form | O, VA | | |
| | Use of hutches or calf boxes for single housing | QN, VA | | |
| | Pair housing | QN, VA | Pair housing should be preferred to single housing | Jensen and Larsen (2014), Costa et al. (2015) |
| | Social contact in single housings | QN, VA | Social contact should be possible in individual housings | BMJV (2001), Jensen and Larsen (2014) |
| | Duration of single housing | O | Calves should not be housed individually longer than 14 d | BMJV (2001), Jensen and Larsen (2014) |
| | Amount of on farm movements of calves | O | | |
| | Method of moving calves on farm | O | | |
| | Bedding material | QN, VA | | |

| Area of interest | Variable | Method of recording[1] | Used recommendations | Source of recommendation |
|---|---|---|---|---|
| (4) Housing and transport | | | | |
| | Renewal of bedding | QO | New bedding material should be provided at least every second day | Camiloti et al. (2012), Heinemann et al. (2020) |
| | Cleaning method for single houses | O | Single houses should be cleaned with water and detergents | Hancox et al. (2013), Heinemann et al. (2020) |
| | Cleaning interval for single houses | O | Single houses should be cleaned after every occupation | Bartels et al. (2010), Heinemann et al. (2020) |
| | Disinfection of single houses | O | Single houses should be disinfected | Hancox et al. (2013), Heinemann et al. (2020) |
| | Disinfection interval for single houses | O | Single houses should be disinfected after every occupation | Hancox et al. (2013), Heinemann et al. (2020) |
| | Rearing of male calves | QN | | |
| | Time of calf transportation and last feeding time | O | Calves should be fed 6 h prior to the transportation | Grigor et al. (2001), DFC-NFACC (2009), Fisher et al. (2014) |
| (5) Calf feeding | | | | |
| | Type of milk used for feeding | QN | Waste milk or milk with high somatic cell counts should not be fed | Aust et al. (2013), Barry et al. (2020), Heinemann et al. (2020) |
| | Usage of milk additives | QN | | |
| | Usage of milk acidifier | QN | | |
| | Warm or cold milk fed | QN | | |
| | Milk feeding plan | O | At least 6 L milk on average should be fed, including a weaning phase | Passillé et al. (2010); Rosenberger et al. (2017); Costa et al. (2019) |
| | Occurrence of cross suckling | QO | | |
| | Differentiation between sexes in feeding calves | O | Differentiation in feeding between sexes should be avoided | Franco et al. (2014), Bellamy (2017), Renaud et al. (2017) |
| | Feeding buckets cleaning method | O | Feeding buckets should be cleaned with water and detergents | Maunsell and Donovan (2008), Trotz-Williams et al. (2008), Heinemann et al. (2020) |
| | Feeding buckets cleaning interval | O | Feeding buckets should be cleaned after each use | Maunsell and Donovan (2008), Heinemann et al. (2020) |
| | Dismantling artificial teats for cleaning | QN | Artificial teats should be dismantled for cleaning | Heinemann et al. (2020) |

| Area of interest | Variable | Method of recording[1] | Used recommendations | Source of recommendation |
|---|---|---|---|---|
| (5) Calf feeding | | | | |
| | Disinfecting feeding buckets | QN | Feeding buckets should be disinfected | Maunsell and Donovan (2008), Heinemann et al. (2020) |
| | Time at which calves have access to water | O | Calves should have access to water before the 14th day (German legal requirement) | BMJV (2001), Wickramasinghe et al. (2019) |
| | Time at which calves have access to roughage | O | Calves should have access to roughage before the 8th day (German legal requirement) | BMJV (2001), Khan et al. (2011) |
| | Time at which calves have access to concentrate | O | Calves should have access to concentrate before the 8th day (German legal requirement) | BMJV (2001), Torsein et al. (2011) |
| (6) Painful procedures | | | | |
| | Time of identification | O | Calves should be ear tagged before the 8th day (German legal requirement) | BMJV (2007), Vasseur et al. (2010) |
| | Person who tags ears | O | | |
| | Checking wound healing after ear | QN | | |
| | Castration of male calves | QN | | |
| | Castration method | O | Burdizzo should be used for castration | Molony et al. (1995), Thüer et al. (2007) |
| | Analgesic for castration | QN | Analgesics should be administered | BMJV (1972) |
| | Sedatives for castration | QN | Sedatives should be administered | BMJV (1972) |
| | Anesthetic for castration | QN | Anesthetics should be administered | Thüer et al. (2007) |
| | Removal of supernumerary teats | QN | Supernumerary teats might lead to interference at milking, risk of mastitis and should be removed | Roberts and Fishwick (2010), Santman-Berends et al. (2012) |
| | Time of teat removal | O | Removal of supernumerary teats in the first 4 weeks p.p. and preferably at disbudding | Waltner-Toews et al. (1986), Roberts and Fishwick (2010), FARM (2020) |
| | Method for teat removal | O | Scalpel blade or curved scissor should be used | Roberts and Fishwick (2010) |
| | Teat removal in presence of a | QN | Veterinarian should be present | Roberts and Fishwick (2010) |
| | Analgesic for teat removal | QN | Analgesics should be administered | Roberts and Fishwick (2010), FARM (2020) |

| Area of interest | Variable | Method of recording[1] | Used recommendations | Source of recommendation |
|---|---|---|---|---|
| (6) Painful procedures | | | | |
| | Sedatives for teat removal | QN | Sedatives should be administered | Roberts and Fishwick (2010), FARM (2020) |
| | Anesthetic for teat removal | QN | Anesthetics should be administered | Roberts and Fishwick (2010), FARM (2020) |
| | Disbudding of calves | QN | | |
| | Use of polled sires | QN | Polled sires should be used | AVMA (2014), Costa et al. (2019) |
| | Person performing disbudding | O | Disbudding should be performed by the same trained, experienced person | DFC-NFACC (2009), Alsaaod et al. (2014) |
| | Fixation for disbudding | QN | | |
| | Group size for disbudding | O | | |
| | Time of disbudding | O | Calves should be disbudded in the first 3 weeks p.p.; disbudding of calves older than 6 weeks only with anesthetics | BMJV (1972), DFC-NFACC (2009) |
| | Method for disbudding | QN | Calves should be disbudded by cauterization | Vasseur et al. (2010), Stafford and Mellor (2011), AVMA (2014) |
| | Disbudding in presence of a veterinarian | QN | Veterinarian should be present | Stafford and Mellor (2011), Bates et al. (2015) |
| | Analgesic for disbudding | QN | Analgesics should be administered | BMJV (1972), Stafford and Mellor (2011), AVMA (2014) |
| | Sedatives for disbudding | QN | Sedatives should be administered | BMJV (1972), Stafford and Mellor (2011), AVMA (2014), Winder et al. (2018) |
| | Anesthetic for disbudding | QN | Anesthetics should be administered | Stafford and Mellor (2011), AVMA, (2014), Flint et al. (2016), Winder et al. (2018) |
| | Description of the disbudding procedure | O | | |
| (7) Animal welfare mindset | | | | |
| | What aspects are important for the | O | | |
| | How important is animal welfare for | NS | | |
| | How important is animal welfare for the | NS | | |

| Area of interest | Variable | Method of recording[1] | Used recommendations | Source of recommendation |
|---|---|---|---|---|
| (7) Animal welfare mindset | | | | |
| | How would you rate the wellbeing of your calves? | NS | | |
| | How could you increase the wellbeing of your calves? | O | | |
| | Which indictors do you use to assess the welfare of your calves? | O | | |
| | Have you invested in the past 6 months to improve the wellbeing of your calves? If yes, how? | O | | |
| | Do you want to invest in the next 6 months to improve the wellbeing of you calves? If yes, how? | O | | |

[1]Method of recording: QN = qualitative nominal (e.g. yes or no); QO = qualitative ordinal (e.g. educational level); C = continuous (e.g. number of cows); O = open question; NS = numerical scale (1 - 10); VA = visual assessment.

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**Supplemental Table S7.2.** Complementary comments of the respondents to the provided questions, with each line indicating a new statement. Identical statements were summarized, and number of mentions are shown in brackets. Answers were translated from German into English.

| Area of interest | Variable | Comments |
|---|---|---|
| (1) Farm Characteristics | | |
| | Sex of the respondent | *No comments* |
| | Age of the respondent | *No comments* |
| | Education level of the | *No comments* |
| | Participation of the respondent in animal welfare training | Training by trade association (n = 3)<br>Training by advisory council (n = 3)<br>Training on low stress stockmanship, trainings by consultation agency or trade association<br>European dairy farmer congress, training by trade association, seminars from advisory council<br>Training by trade association, animal transport training<br>Training by trade association and seminars from advisory council<br>Trainings on calf rearing, seminar on homeopathy<br>Training by trade association, training in low stress stockmanship<br>Training by the veterinarian, recognizing animal welfare in calves and cows<br>Training by trade association for the whole farm<br>Different seminars<br>Several web seminars<br>Trainings on animal health<br>Training at a research facility<br>Working group in calf rearing<br>Seminar on the stress-free cow<br>Training on calving |
| | Herd size | *No comments* |
| | Used breed | 70% Holstein-Friesian, 30% Brown Swiss and Simmental dairy cows<br>Holstein-Friesian, Belgian Blue heifers<br>Brown Swiss and Simmental<br>Mainly Simmental but also some Holstein-Friesian |
| | Responsibility for calf management | Alternating between trainee and owner<br>Farmer and trainee<br>Uncle |

| Area of interest | Variable | Comments |
|---|---|---|
| (1) Farm Characteristics | | |
| | Regular treatment by veterinarian | Vaccinations (n = 2)<br>Vaccination against lung infections (n = 2)<br>Vaccination against rota and corona virus (n = 2)<br>Vaccination against *Trichophyton verrucosum* (n = 2)<br>Treatment against cryptosporidia (n = 2)<br>Vaccination against rota and corona virus as well as lung infections<br>Vaccination against *Trichophyton verrucosum* and against rota and corona virus<br>Vaccination against lung infections, preventive measures against coccidiosis<br>Vaccination against rota and corona virus, treatment with Halocur<br>Vaccination and Halocur treatment<br>Vaccination every two weeks<br>Pain medication for disbudding<br>Visual controlling of calves<br>Regular veterinary herd health care |
| | Regular consultancy by a veterinarian in calf rearing | Consultation with all stockpersons on the farm<br>Girlfriend is a veterinarian<br>Veterinarian comes every 4 weeks<br>Private contact in case of issues<br>For vaccination and to resolve problems with cryptosporidia<br>Checking the health status of calves<br>Only if something new is available<br>Only if health issues occur<br>Only rare visual assessments |
| | Regular consultancy by a consultant in calf rearing | Feeding consultant (n = 5)<br>Advisory council (n = 3)<br>In case of issues, feeding consultant<br>Feeding consultant, not frequently<br>Milk replacer salesman<br>Hired consultation company<br>Animal trader |
| | Mortality 14 d pp. | No losses this year<br>4 calves lost in 2018<br>Mainly caused by diarrhea<br>Irregular peaks |
| | Mortality until weaning | No losses after the first two weeks (n = 5)<br>Issues with coccidiosis |

| Area of interest | Variable | Comments |
|---|---|---|
| (1) Farm Characteristics | | |
| | Diarrhea incidence | Every calf gets diarrhea at least once during the nursing phase |
| | | Every calf older than 2 weeks |
| | | Every calf gets diarrhea but only for a short period |
| | | 20% in the last half year |
| | | 10%, peak after 2 weeks |
| | | High incidences for certain periods |
| | | High incidences if preventive measures are not taken |
| | | Higher incidences after too early regrouping |
| | | Higher incidences, beginning from the third month |
| | | Issue with rota and corona virus |
| | | Rota and corona virus as main reason for diarrhea, but vaccination is also done |
| | | During the change from single to group housing |
| | | Treatment with electrolytes |
| | Respiratory disease incidence | No incidences in the last year (n = 2) |
| | | No issues, vaccination helped |
| | | Shearing the calves in winter, two times a year helped to reduce respiratory diseases; no problem anymore |
| | | Barn is not optimal |
| | | Issues only in autumn |
| | | Every third calf gets a respiratory disease, nearly 15% die |
| | Dystocia incidence | 95% need no help at all |
| | | 95% are easy calving |
| | | 90% without any assistance, 5 severe calving last year |
| | | 80% are easy calving |
| | | 75% are calving without any assistance |
| | | Bull used for breeding caused higher rates of dystocia and still births |
| | | Issues with heifers |
| | | Issues with frequent twin calving |
| | | Use of sexed semen, which helps to reduce the dystocia rate |
| | | Dystocia is rare due to calving on pasture in summer |
| | | Calf cards in a herd register |
| | | National database |
| | | Differentiation between light/ middle and severe calving |
| | | Sexed semen, only female calves |
| | | Every calf that has a rectal temperature over 39°C is treated with antibiotics |
| | Analysis of feces samples | Animal health service collects samples on regular basis |

| Area of interest | Variable | Comments |
|---|---|---|
| (2) Calving management | | |
| | Use of calving pens | *No comments* |
| | Number of calving pens | *No comments* |
| | Number of cows per calving pen | *No comments* |
| | Calving pen used as hospital pen | For cows with lameness<br>In exceptional cases, the calving pen is used for sick cows<br>Sometimes, there is a separated pen for sick cows, but if it is full, calving pen is used |
| | Bedding material | *No comments* |
| | Cleaning method | High pressure cleaner with foam<br>Only removal of bedding, but fresh straw applied daily |
| | Cleaning interval | Once a week manure is partly removed, one third remains. Every 6 weeks complete removal of bedding |
| | Disinfection of calving pens | Application of Desinfleur after removal of bedding<br>Use of Dezidex<br>Use of milking parlor disinfectant<br>KC 5000, agent against *cryptosporidium*<br>Use of an agent recommended by veterinarian<br>Use of an agent from Schauman<br>Use of lime for disinfection<br>Lime after cleaning with high pressure cleaner<br>Not now, but last year after every calving<br>No disinfection, only if the barn is completely empty |
| | Disinfection interval | *No comments* |
| | Usage of mechanical calf puller | Often, I prefer to assist the calving<br>Two to three times this year<br>Two times a year<br>Scarcely, once a year<br>Never used |
| | Dystocia documentation | For every calving<br>Immediately after calving<br>Using the software “Kuhvision”<br>Herd management program<br>National herd database<br>Herd book<br>In case something happens<br>Sometimes |

| Area of interest | Variable | Comments |
|---|---|---|
| (2) Calving management | | |
| | Separation from dam during day calving | At the next milking time (n = 4) |
| | | Immediate separation until 2 p.m. |
| | | Female calves are separated directly, but bull calves are kept with the dam for more than a day |
| | | Before the next feeding time |
| | | At the next feeding time |
| | | Depending on the time of calving |
| | Separation from dam during night calving | Until 10 p.m. the calf gets separated immediately but we do not separate during the night |
| | | After 3 – 4 h, before the morning milking |
| | | At the next morning |
| | | At the next milking time |
| | | At the next feeding time |
| | | Depending on the time of calving |
| | | No later than one day after calving |
| | | Bull calves can stay with the dam for up to three days |
| (3) Colostrum management | | |
| | Measures to control the intake of colostrum | Visual control (n = 2) |
| | | Regular blood sample taken to measure Ig concentration to control workers performance |
| | | We control the intake of colostrum for calving during the day, but not at night |
| | | Every calf gets 4 L via esophageal tube |
| | Time of first meal | Immediate milking of the dam, but not at night |
| | | Immediately, but sometimes later for bull calves |
| | | For calving at night, we feed in the morning |
| | | At the next milking time |
| | | At the next feeding time |
| | | After separation, 12 – 18 h after calving |
| | | After bringing calves into the individual housings |
| | Checking colostrum quality | Refractometer is used (n = 3) |
| | | Colostrum quality is checked by using a colostrum spindle (n = 3) |
| | | Using a refractometer and feeding of a dry cow concentrate which is supposed to increase IgG concentration |
| | | With a colostrum spindle, but not every time |
| | | About half of the colostrum is checked |
| | | Only visual assessment |
| | Amount of colostrum fed | As much as they want to drink |

| Area of interest | Variable | Comments |
|---|---|---|
| (3) Colostrum management | | |
| | Colostrum feeding method | With a bucket, but if calf does not drink at least 3 L, we use an esophageal tube (n = 2)<br>Suckling from the dam, bottle feeding and for 10% we use esophageal tubes<br>Colostrum fed with flasks, but it can also drink from the dam<br>Bottle has a volume of only 2 L<br>Bull calves only suckle from dam<br>No use of esophageal tubes |
| | Using colostrum of first parity cows | Only colostrum of multiparous cows is fed |
| | Having a stock of colostrum | Regular changing of the stock (every seven days) |
| (4) Housing | | |
| | Navel disinfection | Disinfection with blue spray (n = 4)<br>Disinfection with blue spray, cleaning before disinfection<br>Disinfection with blue spray or iodine<br>Disinfection with iodine<br>Navel disinfection is followed by regular controls. If navel gets infected, we treat it with penicillin |
| | Time of navel disinfection | *No comments* |
| | Single housing form | *No comments* |
| | Use of hutches or calf boxes for single housing | *No comments* |
| | Pair housing | *No comments* |
| | Social contact in single housings | *No comments* |
| | Duration of single housing | 6 d for calves that are reared on farm and 14 d for calves to be sold<br>14–21 d, until five animals are over 14 d old<br>14 d in individual housing and only 6 weeks in groups on the farm. Calves are reared on another farm.<br>Female calves for 10 d and male calves for 14 d<br>We want to move them with 14 d, but sometimes they stay in individual housings for up to 3–4 weeks |
| | Amount of on farm movements of calves | Calving pen to single housings, from single housing to first group and then f to the next group |
| | Method of moving calves on farm | Groups are moved with a trailer (n = 2)<br>Self-made barrow out of an old tractor wheel<br>Self-made construction for the wheel loader<br>Self-made boxes |
| | Bedding material | *No comments* |

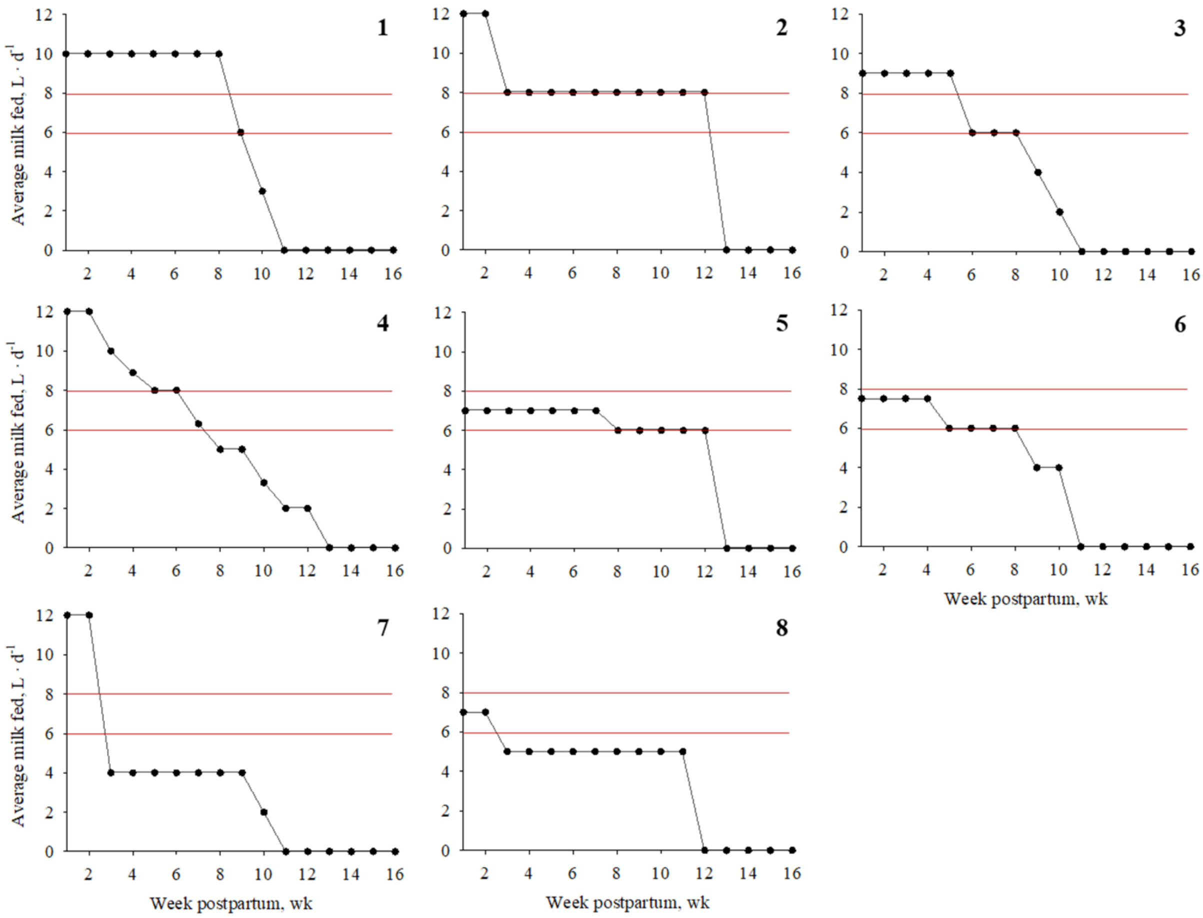
| Area of interest | Variable | Comments |
|---|---|---|
| (4) Housing | | |
| | Bedding material | *No comments* |
| | Renewal of bedding | Every day and sometimes twice a day |
| | Cleaning method for single houses | Single houses are disassembled for every cleaning |
| | Cleaning interval for single houses | After every third occupation |
| | Disinfection of single houses | Milking parlor disinfection agent (n = 2)<br>Agent against *cryptosporidium* (n = 2)<br>Valvanol as disinfection agent<br>Silarit as disinfection agent<br>Neopredisan<br>KC 5000, agent against *cryptosporidium*<br>Sometimes but not regularly<br>Only if there are higher rates of diarrhea |
| | Disinfection interval for single houses | Three times a year |
| | Rearing of male calves | *No comments* |
| | Time of calf transportation and last feeding time | Varying time of transportation<br>Feeding of electrolytes before transportation<br>We feed electrolytes before the transportation in summertime<br>Calves are fed more milk at the meal bevor transportation |
| | Type of milk used for feeding | Waste milk only fed after half of the waiting period is over (n = 5)<br>Waste milk is fed but only from cows that are not treated for mastitis<br>Waste milk and milk from sick cows is only fed to older calves<br>50% milk replacer and 50% whole milk or waste milk<br>Mixture of whole milk, waste milk and milk with high somatic cell count<br>Milk with high somatic cell count and waste milk only rarely fed<br>If we do not have enough whole milk, we also feed milk replacer<br>We want to switch from whole milk to milk replacer<br>Milk replacer from the beginning of the second week, first three weeks whole milk |
| | Usage of milk additives | Milkivit additives against coccidiosis<br>Powder for diarrhea prevention |
| | Usage of milk acidifier | Acidifier only in the summer months |
| | Warm or cold milk fed | *No comments* |
| | Milk feeding technique | Buckets with a teat for the first 14 d, open buckets in groups |

| Area of interest | Variable | Comments |
|---|---|---|
| (5) Calf feeding | | |
| | Milk feeding plan | Additional electrolytes during summer months |
| | Occurrence of cross suckling | Starting with 4 – 6 weeks p.p.<br>Feeders in the groups are not removed to let them suckle<br>Use of chili powder in case of cross suckling<br>Not an issue during the nursing phase, but with heifers in an age of 1 – 1.5 yrs<br>It happens sometimes but not so often that it is an issue |
| | Differentiation between sexes in feeding calves | Male calves get waste milk or milk from cows with high somatic cell counts (n = 4)<br>Less milk for bull calves (n = 3)<br>Bull calves are fed with milk from cows that suffer from mastitis (n = 2)<br>Bull calves only get 5 L milk<br>Holstein-Friesian bulls are fed 3 L twice. Belgian Blue bulls and female calves get milk ad libitum<br>Calves that will be reared get more milk; male calves only get 2.5 L for each meal<br>Bull calves only get 2 L, two times a day<br>Male calves are sold after 14 d and therefore they just get a constant volume<br>Same amount fed, but bull calves are fed with waste milk<br>Same amount of milk fed, but bull calves are also fed with waste milk<br>Male calves are only fed with whole milk or waste milk |
| | Feeding buckets cleaning method | *No comments* |
| | Feeding buckets cleaning interval | *No comments* |
| | Dismantling artificial teats for cleaning | Cleaning feeding buckets in the dishwasher (n = 2)<br>Each new calf gets his own bucket and a new teat (n = 2)<br>Every week the buckets are cleaned properly. I do not have the time to do it daily<br>Not for the daily cleaning, but once a week<br>Once a month<br>Only if the teat is replaced; every 3 – 4 months<br>For every new calf<br>New teat for every new calf<br>Not always but we replace teats often |
| | Disinfecting feeding buckets | We use the milking parlor disinfection agent to disinfect the buckets (n = 4)<br>Daily with milking parlor disinfection agent<br>Cleaning every day with hot water and once a week disinfection with milking parlor disinfection agent<br>Every 6 months with milking parlor disinfection agent<br>Megades as disinfection agent |

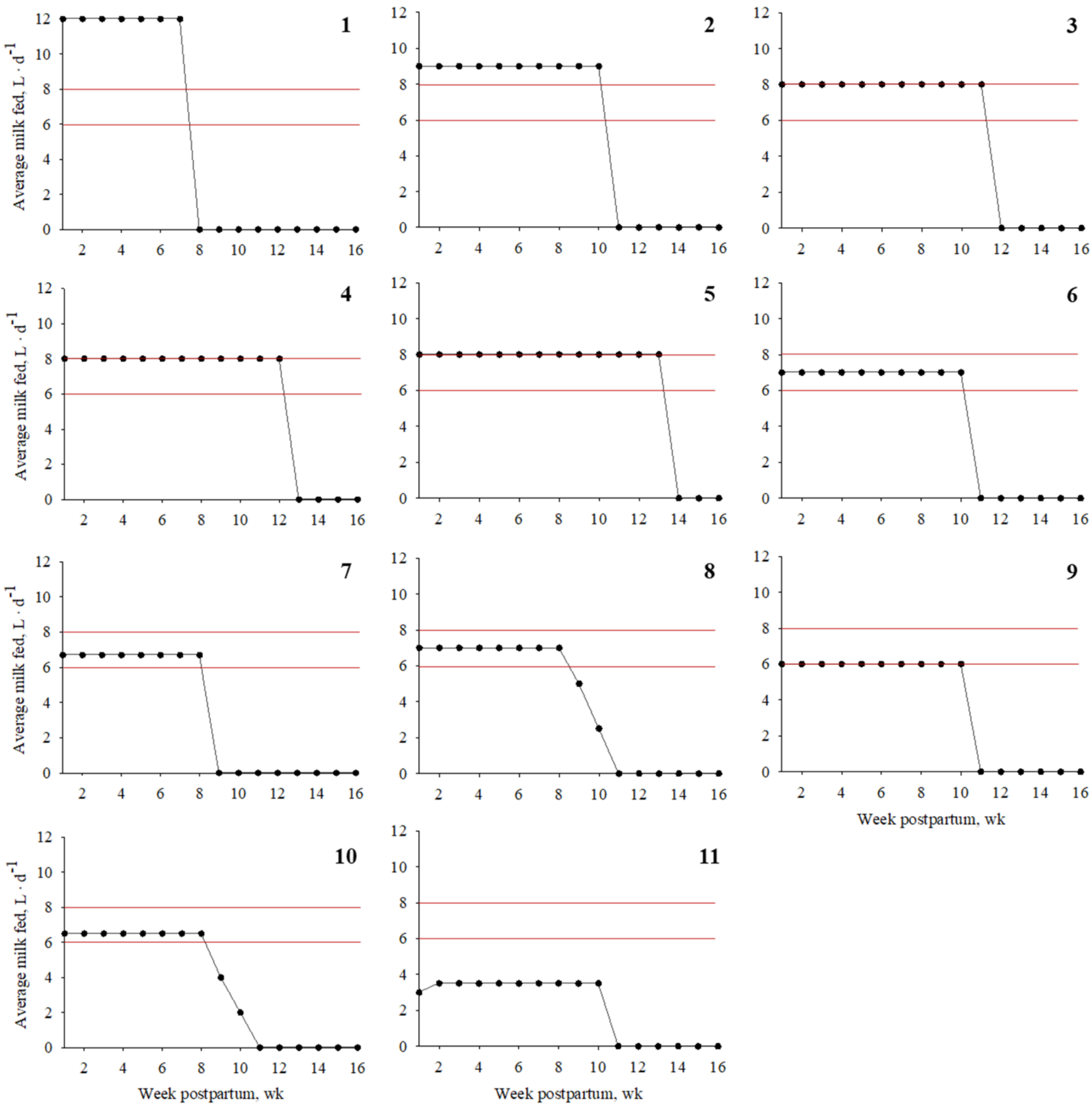
| Area of interest | Variable | Comments |
|---|---|---|
| (5) Calf feeding | | |
| | Time at which calves have access to water | *No comments* |
| | Time at which calves have access to roughage | *No comments* |
| | Time at which calves have access to concentrate | *No comments* |
| (6) Painful procedures | | |
| | Time of identification | We also take other tissue samples for a herd and breeding program |
| | Person who tags ears | Calf gets fixated between the legs for ear tagging (n = 2)<br>Tagging of the ear by fixation between the legs or during feeding<br>Ear tagging in calving pen<br>Ear tagging in calf box or in calf taxi<br>Positioned in front of the calf<br>In calving pen<br>In individual housings from outside the box<br>In small groups, fixation between the legs or while they are laying still<br>Ear tagging while they are laying or sleeping with fixation between the legs<br>Fixation between the legs of the performing person or while calves are lying on the ground<br>Fixation of the head |
| | Checking wound healing after ear tagging | Regular checkup and disinfecting after ear tagging |
| | Castration of male calves | *No comments* |
| | Castration method | *No comments* |
| | Castration in presence of a veterinarian | *No comments* |
| | Analgesic for castration | *No comments* |
| | Sedatives for castration | Every calf is sedated, even if they are hornless |
| | Anesthetic for castration | *No comments* |
| | Removal of supernumerary teats | We are planning to do it, but not yet<br>We remove them, but they occur only rarely and are then removed by the veterinarian |
| | Time of teat removal | Removal of supernumerary teats directly after birth (n = 2)<br>Removal of supernumerary teats when calves are moved to group housings (n = 2)<br>When they are separated from the dam<br>We are not doing it yet, but if we start to remove them, we would do it directly after birth |

| Area of interest | Variable | Comments |
|---|---|---|
| (6) Painful procedures | | |
| | Method for teat removal | *No comments* |
| | Teat removal in presence of a veterinarian | *No comments* |
| | Analgesic for teat removal | *No comments* |
| | Sedatives for teat removal | *No comments* |
| | Anesthetic for teat removal | *No comments* |
| | Disbudding of calves | *No comments* |
| | Use of polled sires | Hornless herd<br>Nearly all calves are hornless<br>Nearly the whole herd is hornless, only 5 calves a year that need to be disbudded<br>Aim is 80% hornless calves<br>30% of all calves are hornless<br>20% of all calves are hornless<br>Around 5% of all calves are hornless<br>Only rarely |
| | Person performing disbudding | The milker |
| | Fixation for disbudding | *No comments* |
| | Group size for disbudding | *No comments* |
| | Time of disbudding | *No comments* |
| | Method for disbudding | *No comments* |
| | Disbudding in presence of a veterinarian | *No comments* |
| | Analgesic for disbudding | *No comments* |
| | Sedatives for disbudding | *No comments* |
| | Anesthetic for disbudding | *No comments* |
| | Description of the disbudding procedure | Disbudding in the morning after feeding, sufficient time until the feeding in the evening<br>Always 4 h after the last feeding<br>Pain medication by veterinarian, blue pray applied afterwards, teat removal in the end by veterinarian |
| (7) Animal welfare mind set | | |
| | What aspects are important for the wellbeing of calves? | *No comments* |
| | How important is animal welfare for you? | *No comments* |

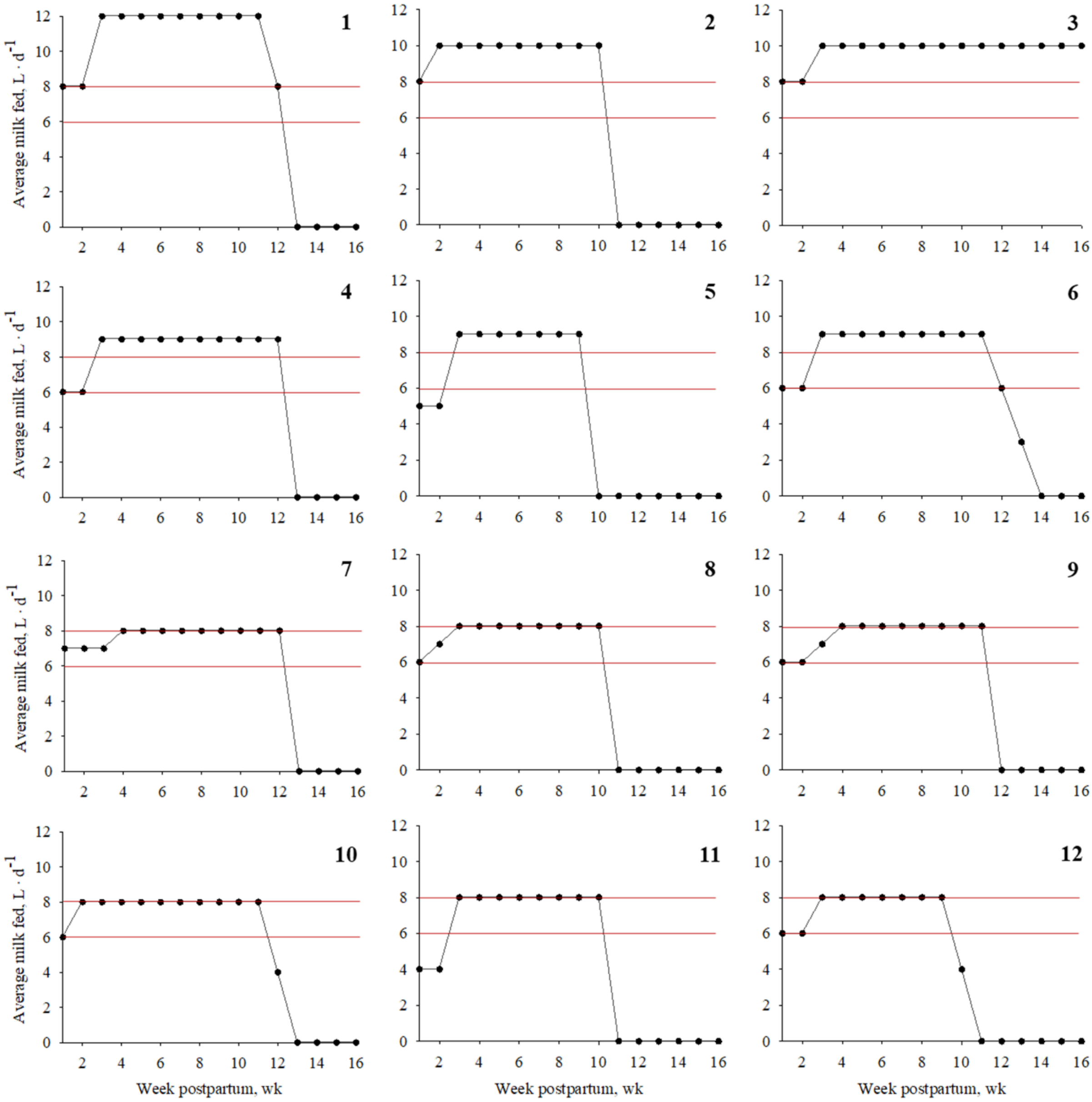
| Area of interest | Variable | Comments |
|---|---|---|
| (7) Animal welfare mind set | | |
| | How important is good animal welfare for the development of calves? | *No comments* |
| | How would you rate the wellbeing of your calves? | *No comments* |
| | How could you increase the wellbeing of your calves? | *No comments* |
| | Which indictors do you use to assess the welfare of your calves? | *No comments* |
| | Have you invested in the past 6 months to improve the wellbeing of your calves? If yes, how? | *No comments* |
| | Do you want to invest in the next 6 months to improve the wellbeing of you calves? If yes, how? | *No comments* |



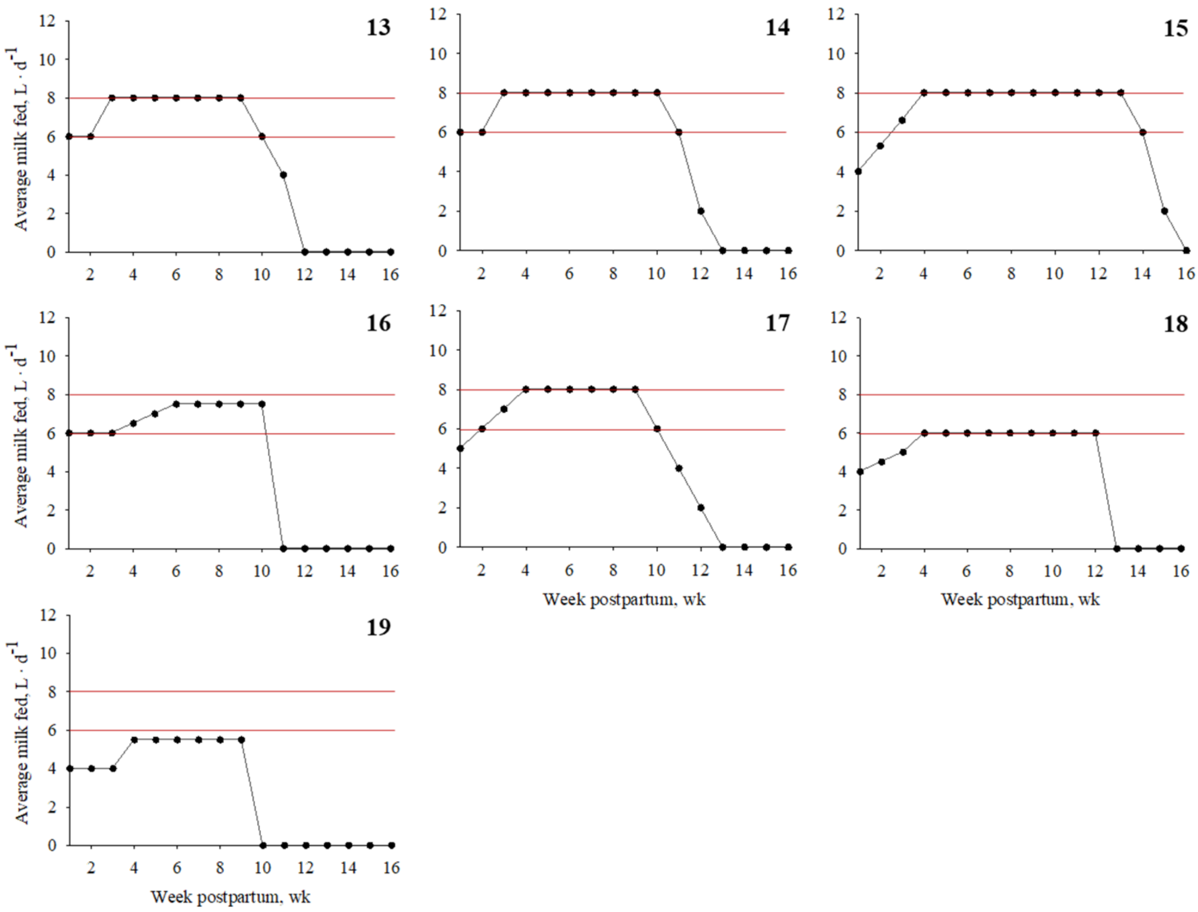

**Supplemental Figures S7.1.** Reported milk feeding plans with decreasing amount of milk fed over time on western German dairy farms (n = 8) ranked by amount of milk fed until weaning (average milk fed multiplied by feeding time). Red thresholds indicate volumes of 6 L (~15% of birth weight) and 8 L of milk (~20% of birth weight). The amount of milk for ad libitum feeding was set to 12 L for visualization purposes.



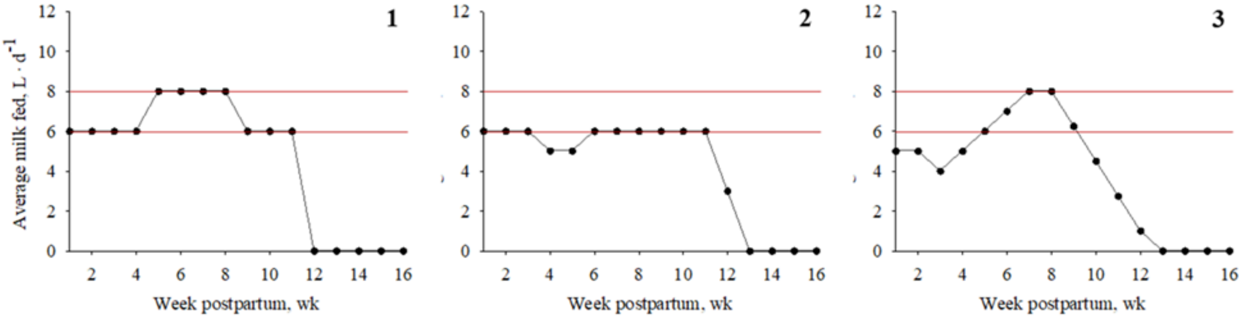

**Supplemental Figure S7.2.** Reported milk feeding plans with constant amount of milk fed over time on western German dairy farms (n = 12) ranked by amount of milk fed until weaning (average milk fed multiplied by feeding time). Red thresholds indicate volumes of 6 L (~15% of birth weight) and 8 L of milk (~20% of birth weight). The amount of milk for ad libitum feeding was set to 12 L for visualization purposes.




**Supplemental Figure S7.3.** Reported milk feeding plans with increasing amount of milk fed over time on western German dairy farms (n = 19) ranked by amount of milk fed until weaning (average milk fed multiplied by feeding time). Red thresholds indicate volumes of 6 L (~15% of birth weight) and 8 L of milk (~20% of birth weight). The amount of milk for ad libitum feeding was set to 12 L for visualization purposes.




**Continuation Supplemental Figure S7.3.** Reported milk feeding plans with increasing amount of milk fed over time on western German dairy farms (n = 19) ranked by amount of milk fed until weaning (average milk fed multiplied by feeding time). Red thresholds indicate volumes of 6 L (~15% of birth weight) and 8 L of milk (~20% of birth weight). The amount of milk for ad libitum feeding was set to 12 L for visualization purposes.




**Supplemental Figure S7.4.** Reported milk feeding plans with fluctuating amount of milk fed over time on western German dairy farms (n = 3) ranked by amount of milk fed until weaning (average milk fed multiplied by feeding time). Red thresholds indicate volumes of 6 L (~15% of birth weight) and 8 L of milk (~20% of birth weight). The amount of milk for ad libitum feeding was set to 12 L for visualization purposes.

## 7.2. Supplemental material for chapter 3

**Supplemental Table S7.3**. Detailed calculated odds ratios and their 95% confidence interval (CI) for wound lesions due to ear tagging (Score 2 = presence of crust or scab, blood or pus discharge) for both ears of 802 assessed unweaned calves of 42 Western German dairy farms.

| | Score 2 | | |
|---|---|---|---|
| Risk factor | Odds ratio | 95% CI | *P*-value |
| Observer 2 vs. Observer 1 | 0.99 | 0.76–1.28 | 0.93 |
| 101–200 cows vs. < 100 cows | 0.73 | 0.54–0.99 | 0.04 |
| > 200 cows vs. < 100 cows | 0.60 | 0.42–0.87 | < 0.01 |
| 3–4 weeks vs. 1–2 weeks of age | 1.78 | 1.22–2.60 | < 0.01 |
| 5–6 weeks vs. 1–2 weeks of age | 1.09 | 0.71–1.67 | 0.70 |
| > 6 weeks vs. 1–2 weeks of age | 0.61 | 0.41–0.91 | 0.02 |
| Group vs. Single housing | 0.81 | 0.56–1.15 | 0.24 |
| > 5 animals vs. Up to 5 animals | 0.79 | 0.58–1.08 | 0.132 |
| Tag on ridge vs. Tag between ridges | 1.51 | 1.19–1.93 | < 0.01 |
| Score 2 vs. Other scoring of adjacent ear | 3.02 | 2.33–3.90 | < 0.01 |
| Score 3 vs. Other scoring of adjacent ear | 1.62 | 0.99–2.62 | 0.05 |

**Supplemental Table S7.4.** Detailed calculated odds ratios and their 95% confidence interval (**CI**) for wound lesions due to ear tagging (Sore 3 = heavy purulent discharge, tissue deformation, or both) for both ears of 802 assessed unweaned calves of 42 Western German dairy farms.

| | Score 3 | | |
|---|---|---|---|
| Risk factor | Odds ratio | 95% CI | *P*-value |
| Observer 2 vs. Observer 1 | 0.09 | 0.03–0.21 | < 0.01 |
| 101–200 cows vs. < 100 cows | 0.78 | 0.46–1.36 | 0.38 |
| > 200 cows vs. < 100 cows | 0.88 | 0.45–1.36 | 0.70 |
| 3–4 weeks vs. 1–2 weeks of age | 0.86 | 0.46–1.64 | 0.68 |
| 5–6 weeks vs. 1–2 weeks of age | 0.48 | 0.20–1.06 | 0.08 |
| > 6 weeks vs. 1–2 weeks of age | 0.31 | 0.15–0.65 | < 0.01 |
| Group vs. Single housing | 0.52 | 0.24–1.05 | 0.08 |
| > 5 animals vs. Up to 5 animals | 2.49 | 1.24–5.35 | 0.01 |
| Tag on ridge vs. Tag between ridges | 1.43 | 0.91–2.23 | 0.12 |
| Score 2 vs. Other scoring of adjacent ear | 1.66 | 0.98–2.82 | 0.06 |
| Score 3 vs. Other scoring of adjacent ear | 4.67 | 2.53–8.54 | < 0.01 |

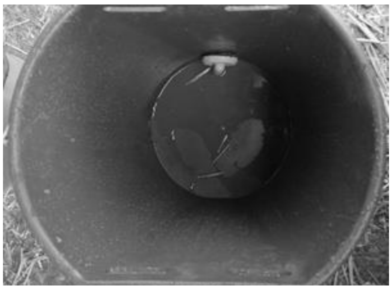
## 7.3. Supplemental material for chapter 4

**Supplemental Table S7.5.** Scoring system used for 20 resource- and animal-based welfare indicators on 42 western German dairy farms.

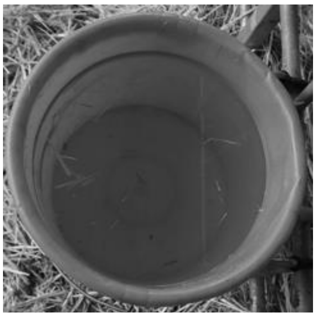
| Access to concentrate | Description | Examples |
|---|---|---|
| Score 0 | Calf has access to concentrate |  |
| Score 1 | Calf has no access to concentrate |  |

| Access to roughage | Description | Examples |
|---|---|---|
| Score 0 | Calf has access to additional roughage (bedding is excluded as defined in German standards) |  |
| Score 1 | Calf has no access to additional roughage (bedding is excluded as defined in German standards) |  |

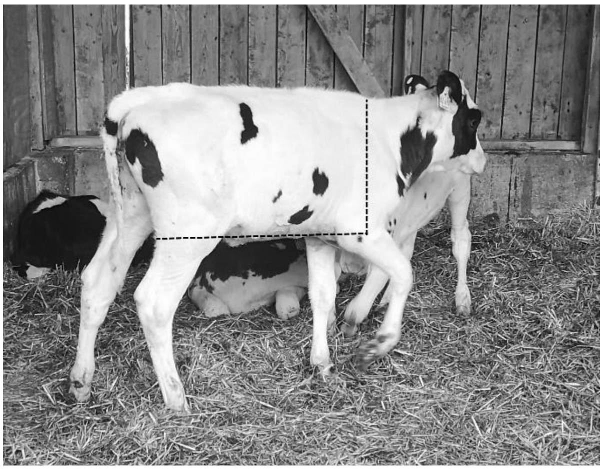
| Access to water | Description | Examples |
| --- | --- | --- |
| Score 0 | Calf has access to water |  |
| Score 1 | Calf has no access to water |  |

| Cleanliness of milk buckets | Description | Examples |
|---|---|---|
| Score 0 | No soiling visible |  |
| Score 1 | Minor milk residues visible |  |
| Score 2 | Coarse soiling |  |

| Cleanliness of feeding trough | Description | Examples |
|---|---|---|
| Score 0 | No soiling visible |  |
| Score 1 | Minor soiling |  |
| Score 2 | Coarse soiling and spoiled feed left |  |

| Cleanliness of water trough | Description | Examples |
|---|---|---|
| Score 0 | Clean drinking water |  |
| Score 1 | Low turbidity, feed residues |  |
| Score 2 | High turbidity, feed residues in water, biofilm development |  |

| Cleanliness of bedding | Description | Examples |
|---|---|---|
| Score 0 | Fresh, clean, dry bedding |  |
| Score 1 | Slightly dirty, slightly damp |  |
| Score 2 | Coarse soiling, wet spots |  |

| Cleanliness of core body | Description | Examples |
|---|---|---|
| Score 0 | < 25% of core body surface is dirty |  |
| Score 1 | > 25% of core body surface is dirty |  |

| Cleanliness of carpal joints | Description | Examples |
|---|---|---|
| Score 0 | Clean carpal joints |  |
| Score 1 | Minor soiled carpal joints |  |
| Score 2 | Coarse soiling, wet carpal joints |  |

| Cleanliness of claws | Description | Examples |
|---|---|---|
| Score 0 | Clean claws |  |
| Score 1 | Slight soiling around the claws |  |
| Score 2 | Thick crust of dirt around claws |  |

| Nesting score | Description | Examples |
|---|---|---|
| Score 0 | Limbs not visible in lying calves |  |
| Score 1 | Limbs partly visible in lying calves |  |
| Score 2 | Limbs fully visible in lying calves |  |

| Underdevelop-ment /Runt | Description | Examples |
|---|---|---|
| Score 0 | Good muscles, ribs not visible, shiny coat |  |
| Score 1 | Lack of muscles, ribs visible, dull coat |  |

| Ear tag wounds | Description | Examples |
| --- | --- | --- |
| Score 0 | No clinical sign of wound healing disorder |   |
| Score 1 | Discharge of pus or blood or tissue deformation or both |   |

| Horn bud inflammation | Description | Examples |
|---|---|---|
| Score 0 | No clinical sign of inflammation |  |
| Score 1 | Reddening and swelling around removed horn bud |  |

| Navel inflammation | Description | Examples |
|---|---|---|
| Score 0 | Normal, pain free to handle |  |
| Score 1 | Swelling, inflammation of navel area |  |

| Diarrhea | Description | Examples |
| --- | --- | --- |
| Score 0 | Solid or paste-like feces |  |
| Score 1 | Watery fluid feces, pungent smell |   |

| Coughing | Description | Examples |
|---|---|---|
| Score 0 | Normal breathing |  |
| Score 1 | Spontaneous, or continuous coughing |  |

| Visible skin injuries | Description | Examples |
|---|---|---|
| Score 0 | Absence of lesions or wounds |  |
| Score 1 | Visible lesions or wounds |  |

| Sucked teats | Description | Examples |
|---|---|---|
| Score 0 | Normal tissue around teats | |
| Score 1 | Swollen tissue around teats | |

**Supplemental Table S7.6.** Calculated odds ratios and 95% confidence interval (CI) of the effect of evaluated influencing factors on the outcome of 20 assessed animal welfare indicators on 42 western German dairy farms. Not assessable data is shown as “na”.

| | Access to concentrate | | |
|---|---|---|---|
| Influencing factor | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.55 | 0.31–0.95 | 0.03 |
| Temperature (°C) | 0.84 | 0.78–0.91 | < 0.001 |
| Rainfall (L/m$^2$) | 0.97 | 0.87–1.10 | 0.62 |
| Calf age (d) | 0.97 | 0.96–0.98 | < 0.001 |
| Calf sex (female vs male) | 0.69 | 0.38–1.30 | 0.23 |
| Group size (no. calves) | 0.63 | 0.56–0.70 | < 0.001 |

| | Access to roughage | | |
|---|---|---|---|
| Influencing factor | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.98 | 0.60–1.59 | 0.93 |
| Temperature (°C) | 0.96 | 0.89–1.02 | 0.20 |
| Rainfall (L/m$^2$) | 0.95 | 0.86–1.05 | 0.35 |
| Calf age (d) | 0.96 | 0.95–0.97 | < 0.001 |
| Calf sex (female vs male) | 0.79 | 0.47–1.33 | 0.37 |
| Group size (no. calves) | 0.84 | 0.78–0.90 | < 0.001 |

| | Access to water | | |
|---|---|---|---|
| Influencing factor | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.80 | 0.46–1.37 | 0.41 |
| Temperature (°C) | 1.17 | 1.08–1.26 | < 0.001 |
| Rainfall (L/m$^2$) | 1.12 | 1.01–1.25 | 0.039 |
| Calf age (d) | 0.99 | 0.97–1.00 | 0.017 |
| Calf sex (female vs male) | 1.07 | 0.61–1.89 | 0.80 |
| Group size (no. calves) | 0.56 | 0.47–0.66 | < 0.001 |

| | Cleanliness milk bucket | | |
|---|---|---|---|
| Influencing factor | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.33 | 0.20–0.55 | < 0.001 |
| Temperature (°C) | 1.16 | 1.09–1.24 | < 0.001 |
| Rainfall (L/m$^2$) | 0.87 | 0.79–0.95 | 0.004 |
| Calf age (d) | 1.01 | 1.00–1 02 | 0.021 |
| Calf sex (female vs male) | 0.35 | 0.22–0.57 | < 0.001 |
| Group size (no. calves) | 0.79 | 0.74–0.85 | < 0.001 |

| | Cleanliness water | | |
|---|---|---|---|
| Influencing factor | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.43 | 0.26–0.70 | < 0.001 |
| Temperature (°C) | 0.93 | 0.88–0.99 | 0.031 |
| Rainfall (L/m$^2$) | 1.11 | 0.99–1.25 | 0.067 |
| Calf age (d) | 1.01 | 1.01–1.02 | < 0.001 |
| Calf sex (female vs male) | 1.12 | 0.64–1.99 | 0.70 |
| Group size (no. calves) | 1.02 | 0.97–1.07 | 0.43 |

| Influencing factor | Cleanliness feed trough | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.28 | 0.13–0.56 | < 0.001 |
| Temperature (°C) | 0.80 | 0.74–0.86 | < 0.001 |
| Rainfall (L/$m^2$) | 1.70 | 1.45–2.01 | < 0.001 |
| Calf age (d) | 1.02 | 1.01–1.03 | < 0.001 |
| Calf sex (female vs male) | 0.29 | 0.14–0.61 | < 0.001 |
| Group size (no. calves) | 1.09 | 1.02–1.15 | 0.008 |

| Influencing factor | Cleanliness bedding | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.53 | 0.35–0.81 | 0.003 |
| Temperature (°C) | 0.98 | 0.93–1.03 | 0.48 |
| Rainfall (L/$m^2$) | 1.06 | 0.97–1.16 | 0.20 |
| Calf age (d) | 1.02 | 1.02–1.03 | < 0.001 |
| Calf sex (female vs male) | 0.56 | 0.36–0.89 | 0.012 |
| Group size (no. calves) | 0.92 | 0.87–0.96 | < 0.001 |

| Influencing factor | Cleanliness carpal joints | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.14 | 0.08–0.25 | < 0.001 |
| Temperature (°C) | 0.93 | 0.88–0.98 | 0.007 |
| Rainfall (L/$m^2$) | 0.97 | 0.87–1.07 | 0.52 |
| Calf age (d) | 1.02 | 1.02–1.03 | < 0.001 |
| Calf sex (female vs male) | 1.20 | 0.73–1.99 | 0.47 |
| Group size (no. calves) | 0.98 | 0.93–1.03 | 0.35 |

| Influencing factor | Cleanliness claws | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.16 | 0.09–0.26 | < 0.001 |
| Temperature (°C) | 0.99 | 0.93–1.06 | 0.86 |
| Rainfall (L/$m^2$) | 0.87 | 0.78–0.97 | 0.013 |
| Calf age (d) | 1.03 | 1.02–1.04 | < 0.001 |
| Calf sex (female vs male) | 1.05 | 0.56–2.01 | 0.89 |
| Group size (no. calves) | 1.19 | 1.12–1.26 | < 0.001 |

| Influencing factor | Nesting score | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.88 | 0.46–1.69 | 0.71 |
| Temperature (°C) | 1.18 | 1.09–1.28 | < 0.001 |
| Rainfall (L/$m^2$) | 1.07 | 0.94–1.22 | 0.34 |
| Calf age (d) | 0.99 | 0.98–1.00 | 0.018 |
| Calf sex (female vs male) | 0.65 | 0.32–1.28 | 0.21 |
| Group size (no. calves) | 0.97 | 0.90–1.03 | 0.32 |

| Influencing factor | Runt | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | na | na | na |
| Temperature (°C) | 0.90 | 0.76–1.06 | 0.23 |
| Rainfall (L/m$^2$) | 1.15 | 0.84–1.54 | 0.36 |
| Calf age (d) | 1.00 | 0.98–1.02 | 0.91 |
| Calf sex (female vs male) | 0.31 | 0.10–1.08 | 0.051 |
| Group size (no. calves) | 1.10 | 0.95–1.27 | 0.18 |

| Influencing factor | Hypothermia | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 2.04 | 1.14–3.70 | 0.017 |
| Temperature (°C) | 0.91 | 0.83–0.99 | 0.038 |
| Rainfall (L/m$^2$) | 1.02 | 0.90–1.15 | 0.71 |
| Calf age (d) | 0.99 | 0.98–1 00 | 0.046 |
| Calf sex (female vs male) | 0.66 | 0.37–1.22 | 0.17 |
| Group size (no. calves) | 0.98 | 0.90–1.06 | 0.61 |

| Influencing factor | Hyperthermia | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 2.06 | 0.98–4.30 | 0.053 |
| Temperature (°C) | 1.11 | 1.00–1.24 | 0.047 |
| Rainfall (L/m$^2$) | 0.88 | 0.71–1.05 | 0.20 |
| Calf age (d) | 1.00 | 0.99–1.02 | 0.68 |
| Calf sex (female vs male) | 0.83 | 0.38–1.97 | 0.65 |
| Group size (no. calves) | 1.03 | 0.95–1.10 | 0.51 |

| Influencing factor | Skin injuries | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.16 | 0.06–0.41 | < 0.001 |
| Temperature (°C) | 1.13 | 1.02–1.24 | 0.016 |
| Rainfall (L/m$^2$) | 0.92 | 0.75–1.11 | 0.41 |
| Calf age (d) | 0.99 | 0.98–1.00 | 0.13 |
| Calf sex (female vs male) | 0.60 | 0.28–1.36 | 0.20 |
| Group size (no. calves) | 1.22 | 1.13–1.32 | < 0.001 |

| Influencing factor | Ear tag wounds | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.40 | 0.26–0.62 | < 0.001 |
| Temperature (°C) | 1.01 | 0.96–1.07 | 0.66 |
| Rainfall (L/m$^2$) | 0.96 | 0.88–1.05 | 0.37 |
| Calf age (d) | 0.97 | 0.97–0.98 | < 0.001 |
| Calf sex (female vs male) | 1.04 | 0.63–1.69 | 0.89 |
| Group size (no. calves) | 0.97 | 0.93–1.02 | 0.25 |

| Influencing factor | Horn bud inflammation | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.16 | 0.03–0.64 | 0.012 |
| Temperature (°C) | 0.91 | 0.73–1.11 | 0.37 |
| Rainfall (L/m$^2$) | 0.88 | 0.57–1.33 | 0.56 |
| Calf age (d) | 0.98 | 0.96–1.01 | 0.17 |
| Calf sex (female vs male) | na | na | na |
| Group size (no. calves) | 1.12 | 0.98–1.29 | 0.091 |

| Influencing factor | Navel inflammation | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 1.27 | 0.56–2.84 | 0.56 |
| Temperature (°C) | 0.94 | 0.84–1.06 | 0.33 |
| Rainfall (L/m$^2$) | 0.98 | 0.82–1.15 | 0.84 |
| Calf age (d) | 0.97 | 0.94–0.99 | 0.002 |
| Calf sex (female vs male) | 0.25 | 0.12–0.50 | < 0.001 |
| Group size (no. calves) | 0.98 | 0.85–1.11 | 0.79 |

| Influencing factor | Sucked teats | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | na | na | na |
| Temperature (°C) | 1.14 | 0.95–1.40 | 0.18 |
| Rainfall (L/m$^2$) | 0.79 | 0.53–1.11 | 0.20 |
| Calf age (d) | 1.06 | 1.03–1.08 | < 0.001 |
| Calf sex (female vs male) | na | na | na |
| Group size (no. calves) | 0.87 | 0.73–1.01 | 0.077 |

| Influencing factor | Coughing | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 0.59 | 0.26–1.22 | 0.17 |
| Temperature (°C) | 0.91 | 0.83–0.99 | 0.032 |
| Rainfall (L/m$^2$) | 1.03 | 0.88–1.19 | 0.71 |
| Calf age (d) | 1.01 | 1.00–1.02 | 0.015 |
| Calf sex (female vs male) | 1.17 | 0.52–2.97 | 0.73 |
| Group size (no. calves) | 1.04 | 0.96–1.12 | 0.29 |

| Influencing factor | Diarrhea | | |
|---|---|---|---|
| | Odds ratio | 95% CI | *P*-value |
| Observer (1 vs. 2) | 1.30 | 0.70–2.38 | 0.40 |
| Temperature (°C) | 0.88 | 0.81–0.96 | 0.005 |
| Rainfall (L/m$^2$) | 0.94 | 0.82–1.06 | 0.36 |
| Calf age (d) | 0.97 | 0.96–0.99 | < 0.001 |
| Calf sex (female vs. male) | 1.10 | 0.61–2.07 | 0.76 |
| Group size (no. calves) | 1.00 | 0.92–1.07 | 0.93 |

## 7.4. Supplemental material for chapter 5

**Supplemental Table S7.7.** Methods used to assess animal welfare related behavior of 12 group-housed, unweaned dairy calves.

| Variable | QBA[1] (Modified after Wemelsfelder et al., 2009) | sQBA (Sant' Anna et al., 2013) | RSH (Krohn et al., 2003) | NOT (Krohn et al., 2003) |
|---|---|---|---|---|
| Duration | 20 min | 30 s/calf | 5 min | 5 min |
| Observational points | 8 fix points | no fix point | one fix point | one fix point |
| Parameters | 20 fixed terms[2] (active, agitated, apathetic, bored, calm, content, distressed, fearful, friendly, frustrated, happy, indifferent, inquisitive, irritable, lively, playful, positively occupied, relaxed, sociable, uneasy) | 12 fixed terms (active, agitated, apathetic, attentive, calm, curious, distressed, fearful, happy, irritable, positively occupied, relaxed) | first approach, contact duration, shortest distance, position in pen, orientation behavior | first approach, contact duration, shortest distance, position in pen, orientation behavior |
| Documentation | 125 mm visual scale | 125 mm visual scale | written, video | written, video |
| Objects | - | - | 2 test persons (blue overall, red t-shirt) | exercise ball (blue), umbrella (black) |
| Requirements | | | | |
| Time | 20 min | 30 s/calf | 5 min | 5 min |
| Staff | 1 person | 1 person | 1 person | 2 persons |
| Material | - | - | new object | new objects |
| Training | One pre-test training | One pre-test training | - | - |

[1]QBA = Qualitative Behavior Assessment; sQBA = simplified Qualitative Behavior Assessment; RSH = Reaction to Stationary Human Test; NOT = Novel Object Test.

[2]20 most often used terms in Wemelsfelder et al., 2009, Brscic et al., 2009, Andreasen et al., 2013, Bokkers et al., 2012, Sant'Anna and Paranhos da Costa, 2013, Ellingsen et al., 2014, Popescu et al., 2014, Kirchner et al., 2016, and Brscic et al., 2019.

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# Publications and presentations

### Peer-reviewed journal articles

**Hayer, J. J.**, D. Nysar, A. Schmitz, C. D. Leubner, C. Heinemann, and J. Steinhoff-Wagner. 2022. Wound lesions caused by ear tagging in unweaned calves: Assessing the prevalence of wound lesions and identifying risk factors. Animal, 16:100454. https://doi.org/10.1016/j.animal.2022.100454.

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**Hayer, J. J.**, D. Nysar, C. Heinemann, C. D. Leubner, and J. Steinhoff-Wagner. 2021. Implementation of management recommendations in unweaned dairy calves in western Germany and associated challenges. J. Dairy Sci., 104:7039–7055. https://doi.org/10.3168/jds.2020-19829.

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### Book contributions

**Hayer, J. J.**, B. Petersen, and J. Steinhoff-Wagner. 2018. Extrinsische Qualitätskriterien in der Wertschöpfungskette Milch. Pages 125–163 in Qualitätsmerkmal Tierwohl. C. Gothe, and B. Petersen, ed. tredition, Bonn, Germany.

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**Hayer, J. J.**, F. Burkhardt, and J. Steinhoff-Wagner. 2021. Drinking behavior as an indicator for the drinking water quality in dairy cows. Page 71 in Proceeding of the 75th digital Conference of the German Society of Nutrition Physiology, 16–18 March 2021.

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**Hayer, J. J.**, S. Thiele, J. Heinke, J. Baumeister, and J. Steinhoff-Wagner. 2018. Kälberfütterung in den ersten Lebenswochen – Eine Umfrage zum Status Quo. Paper presented at the DGFZ- und GFT-Vortragstagung, 12–13 September 2018, Bonn, Germany.