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Review Article

Understanding Calf Behavioral Responses to Environmental Changes and Challenges: An Applied Update

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ABSTRACT

In most of the artificial raising operations, separation of dairy calves from their dams immediately after birth and reared under a variety of housing and feeding systems, expose them to different environmental challenges. The objective of this review article was to describe how environmental changes and challenges influence the health and behavior of young calves. Natural behavior, health, and welfare of the calves may be affected when they are reared indoors apart from their dams with another mate. Fresh perspectives on calf nourishment strategies (e.g., intensified vs. conventional milk feeding, and forage feeding) and housing (group or pair vs. individual) have been developed to assimilate the natural environment of calves. In recent years, based on scientific evidence a positive relationship between early-life calf health and later performance of dairy heifers has been indicated. Chronic exposure to stressors may lead to chronic inflammation, resulting in increased infectious disease and suppressed animal performance. Therefore, an effective diagnostic tool for the identification and prediction of the health status and welfare of calves would be to monitor the behavior of calves regularly on the farm. The main factors affecting the behavior of calves and their subsequent productivity are, nutrition and feeding programs, ambient temperatures, incidences of diseases as well as housing systems. Genetics can affect calf response to environmental alterations. In general, it alleviates stress and improves herd profitability and sustainability for producers and farmers by understanding the calves' behavior in response to environmental challenges.

1. Introduction

As the immune and digestive systems are adapting to the extra-uterine life, the pre-weaning period could be highly stressful for calves[1,2]. During the time that the immune system is not completely developed, dairy calves may be negatively influenced by environmental stressors. As such, the health status and growth of pre-weaned dairy calves are believed to be critical in the future productivity of dairy herds[3,4]. In general, based on the European welfare quality protocol[5], calf welfare is defined by monitoring at least four environmental criteria, including proper nutrition, housing, behavior, and health, which may have a key role in determining the pre-weaning calf performance. Among these factors, calf behavior may be influenced by several factors, such as calf personality, milk and starter feeding strategies, housing type, and disease incidence. It would be helpful to understand the normal behavior of calves, such as when they come into contact with their dam and other members of the herd so that it can be detected soon if the environment is deficient for calves. Changes to calves' behavior can be a rapid and reliable indicator of their health status, particularly where time is a limiting factor for the management of sick calves due to disease incidence[6].

As noted above, calf welfare can be determined according to their behavior. Social and playing behaviors, feeding, and disease behaviors are considered as main behavioral factors that are altered in response to differing environmental conditions. Dairy calves are socially

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motivated as the social contact may provide benefits for them. Although social isolation in the early stages of life is associated with behavioral problems, inability to cope with new environments and cognitive development in dairy calves[7], group housing is an attempt to develop the social skills of calves and imitate their natural raising condition[8]. It seems that dry matter intake (DMI) and weight gain (WG) of calves are increased in group raising systems[7]. Recently, Ahmadi et al.[9] suggested that early grouping of calves (EG, aged 28 days) had positive effects on nutrient intake and growth performance when compared with late grouping (LG, aged 70 days). In addition, EG calves had lower standing frequency and greater eating time than their LG counterparts[7]. Despite such positive effects, regarding the health status of calves especially at very young ages, group housing of calves can be challenging. This concern has recently been reviewed by Costa et al.[7]. Feeding behaviors, such as eating, ruminating, standing, and non-nutritive behaviors (tongue rolling, licking objects, and bedding materials consumption) are also directly related to animal health and well-being[10]. Feeding methods of milk and solid feed may alter the feeding behavior of calves, influencing their growth performance and productivity in pre- and post-weaning periods[11]. Moreover, monitoring the feeding behavior and activity of individual calves continuously using new technologies, such as automated calf feeders and activity monitors has been proposed as a useful strategy in the early detection and treatment of disease on-farm[12].

Therefore, understanding calf behavior in different environmental conditions may provide practical insights into profitable and sustainable calf management.

2. Natural vs. artificial rearing systems

To understand how calves respond to environmental changes, it is necessary to know calf behavior in natural or semi-natural rearing systems. In nature likewise beef production systems, the newborn calf is nursed by the dam and gradually weaned, approximately at the age of 8-10 months[13]. The calf totally depends on the milk supplied by the dam in early stages of life until the bond between mother and calf is reduced as lactation progresses and the calf can graze alongside the mother and other herd members[13,14]. During infancy, the calf will be nursed by the dam 8-12 times per day, approximately lasting 10 minutes for each time[15]. Over time, the calf is introduced to the herd, and the social development is initiated by interacting with other calves and adults[16]. As the weaning time approaches, maternal nursing and surveillance gradually decrease and stop. As such, the mother may behave aggressively with her young calf during weaning. In general, the cow-calf relationships can be classified into three stages including, the first month of life at which the calf is fully dependent on mother care, the rest of the pre-weaning period during which the calf reintegrates into the herd to develop social skills, and weaning time at which the maternal nursing is decreased and finally stops[13]. Expressing social behaviors, suckling large volumes of milk with high frequencies, and smooth and gradual weaning transition are the most profound features of rearing calves in natural or semi-natural systems[17-19].

The conventional or artificial rearing system is different from the natural one. In this popular system a few hours after parturition, calves are separated from dams and move to individual housing systems, including individual pens, hutches, and iron boxes. Accessibility to milk or milk alternatives is limited (10% of body weight) during the pre-weaning period[4]. In addition, since feeding frequency is limited to two or three times a day, milk feeding is done manually using pacifier-equipped bottles or plastic buckets[4]. Intrinsically, the weaning process occurs earlier. Indeed, limited access to milk or milk alternatives may lead to stimulated solid feed intake promoting rumen development and allowing calves to be weaned at very young ages[20,21]. The conventional rearing system may provide some benefits turning it into a preferred worldwide system (60% in Europe[22], and 75% in the U.S[23]). Control of colostrum and milk feeding levels, reduced cross-sucking, and lower risk of disease transmission (diarrhea and respiratory diseases) are the main advantages of rearing calves individually[24,25]. However, in recent years, the conventional rearing systems have been challenged by several authors, especially from welfare and growth perspectives[4,11]. It is believed that a set of management practices (e.g. individual housing and limited milk feeding) performed in conventional systems may restrict the growth rate and well-being of calves in the pre-weaning period that can be extended into the productive cycle of calves as adult dairy cows[4]. Calves that spent more time with their mothers for about 4 days were more capable of being engaged in social play behaviors and coping with the new environment[26]. Recently, the long-term effects of social isolation on the physiology and behavior of humans and animals have been reviewed[27]. As such, the role of epigenetic mechanisms and non-coding RNA in response to prolonged social isolation has been studied[26]. Impaired neurogenesis in the olfactory bulb, ventral hippocampus, and dentate gyrus is believed to be a consequence of social deprivation in animals[27]. Moreover, the hypothalamic-pituitary axis may be affected by social isolation[27]. In rodent models, chronic social separation may lead to some behavioral responses, such as aggressive behaviors against a submissive intrude[28,29]. There is strong evidence to indicate that restrictions on early life in a calf's environment, such as separation from the dam can affect WG and eventual performance of calves,[30]. In addition, reduced fear of novel environments, new feeds, and unfamiliar calves was observed among calves raised with their dams[31-33]. Such behavioral responses were evident several weeks or years following isolation. Recently, a confrontation test has demonstrated that vigilance had increased in maternal-reared calves[34]. Locomotion was also higher in motherless calves than counterparts with maternal contacts during the day. It is concluded that calves reared alongside their dams showed greater social skills and more desire for social contacts than motherless calves. Pérez-Torres et al.[35] compared separated calves

with those in continuous contact with their dams or those with restricted suckling (30 minute per day from day 34 until weaning at the age of 150 day). After 4 months it was shown that temporary separation of calves aged 33 days, for about 72 hours affected the weaning distress significantly. The long-term impacts of cow-calf contact and early isolation have been reviewed[36]. Longer contact with mothers led to normal social behavior in calves and reduced abnormal behavior, and responses to stressors[36]. However, a study conducted to examine the role of early isolation on the first lactation performance of calves, indicated that pre-weaning isolation had no effects on their first lactation milk yield traits[37,38]. It seems that cow-calf contact and the role of isolation on the performance of both the infant and the dam is multilateral. Even though early isolation may have some behavioral and welfare issues, it has been reported that prolonged cow-calf bond may restrict ovarian activity by inhibiting gonadotropin-releasing as well as luteinizing hormones. Thus, more research is needed to determine the short- and long-term effects of these two rearing strategies (early isolation vs. dam-calf contact) on the productivity of the cow and calf.

3. Personal traits, calf behavior, and performance

As discussed above, rearing systems may affect the behavior of calves in short and long periods causing welfare and productive issues. For instance, pair housing may lead to greater feed intake and WG in comparison with individual housing[39,40]. Nevertheless, the calf response to stressors may be different among individuals[41]. In other words, in a similar environment, calves may behave differently. It seems that the calves' personality influences how they react to novel environments, such as dietary changes, moving across the pens, and communication with other herd-mates[41]. Personality in dairy calves can be defined as three main concepts including, exploration, fear or reactivity, and sociability[41]. It is believed that such personal traits are associated with the growth and productivity of ruminant animals[42]. However, animal welfare may be reduced if they cannot respond positively to handling[42]. Investigating the effects of personality and weaning method on feeding behavior of Norwegian red calves revealed that playful/exploratory calves had greater milk and starter intakes per day throughout the study, whereas vocal/active calves consumed less milk and starter over the experimental period[43]. This is concluded that despite the relationships between personality and performance, feeding behavior and growth were not affected by the weaning method. The gradual weaning according to the starter intake of each calf may provide an opportunity to wean calves based on their individual needs[17]. Post-weaning body weight of calves may be influenced by personality, moreover, exploratory and active calves may get greater final body weight. Fearful calves were weaned earlier and slow learner calves were weaned at later ages. The results of the study conducted by Neave et al.[41] indicated that early starter eating and total eating of starter feed could be considered the best measures to predict calf weaning age. In addition, calves that start to eat starter at an early age seem well-behaved during weaning. Similarly, Neave et al.[41] indicated that exploratory-active calves ate the starter feed at early ages and had greater average daily gain during the study[41]. On the other hand, unrewarded visits to automated milk feeders were greater for interactive and vocal-inactive calves[41]. It was concluded that personality traits affect calf feeding behavior and performance during the weaning period[42,44].

Dairy calves will consume various amounts of milk when it is offered *ad libitum*[41]. Marcé et al.[22] reported that milk intake varies in calves during the first week of life, resulting in different WG. In an aligned study, calves with high milk feeding frequency and fast drinking abilities gained significantly more weight than calves with lower milk feeding frequency and slower drinking traits[22]. It is crucial to note that calf personality as well as feeding patterns developed in early life, may influence feeding behavior as an adult cow[45-47]. Feeding patterns are partly flexible and can remain consistent over time[41]. Using nutritional and management strategies to concurrently promote milk, starter, and water intake in the early stages of life could serve as the success triangle in calf raising[48]. Such a hypothesis would be based on the personal characteristics of calves that were discussed above. It seems that some differences observed in weaning weight, pre, and post-weaning performance among farms could be explained through differences in the calves' personality traits. Consequently, characterizing calves with different personalities can provide a practical insight to manage calves based on their inherent needs.

4. Feeding strategies and calf behavior

4.1. Milk feeding

The main part of the newborn calves' nutritional budget during the first months of life contains nutrients, which are produced from whole milk or milk alternative[11]. Consequently, milk-feeding strategies may influence the feeding behavior and welfare of calves[11]. Conventionally, newborn calves are fed approximately 8-10 percent of body weight to stimulate solid feed intake and wean calves in early ages[11]. This feeding system provides limited amounts of milk which is different from what happens in nature[11]. In the natural rearing systems, newborns are fed at least twice a day as much milk (from their mothers) as conventionally milk-fed calves. Moreover, calves on conventional milk feeding programs are mostly housed in individual pens, boxes, or hutches until weaning and then moved to large group pens[41]. It is believed that this system may restrict calf growth and welfare of pre-weaning calves[3]. The intensified or *ad libitum* milk feeding system is referred to as a system in which whole milk or milk replacers are fed about 20 percent of body weight[11]. It is argued that the mentioned method is close to the natural system, leading to greater weight gain, health, and welfare

of calves in the pre-weaning period[49,50]. In a study to compare the role of milk feeding level (*ad libitum* vs. restricted for about 5 L/d) on short and long-term behavioral development of dairy calves, diurnal feeding pattern was different between treatments[51]. The calves with restricted milk feeding had greater variability in feeding time and meal size relative to *ad libitum* fed calves during the week after weaning. Differences in feeding patterns disappeared over time between treatments. In adult dairy cows, variability in feeding patterns may be related to health and welfare issues[51]. It has been reported that cows prone to sub-acute ruminal acidosis may exhibit different diurnal feeding patterns[52]. As a result, milk-feeding strategies may have health outcomes during the weaning transition. It seems that *ad libitum* milk feeding of calves during the first weeks of life provides an opportunity to develop their feeding patterns[53]. Calves with *ad libitum* fed spent more time eating relative to restricted-fed calves (45-60 minutes/day vs. 10 minutes/day for *ad libitum* and restricted-fed calves, respectively), resembling their natural environment. It is believed that the conventional or restricted milk-feeding method reduces calf welfare,[54] which is characterized by increased hunger[54] and reduced play behavior[55]. Similarly, Rosenberger et al.[56] demonstrated that calves fed less milk (6 L/d) had greater unrewarded visits to the milk feeder than those fed higher amounts of whole pasteurized (12 L/d) milk. Persistent hunger in less milk-fed calves is indicated. It seems that the amounts of milk fed by calves have more profound effects on their hunger behavior and welfare than feeding frequency. In a study to compare feeding behavior of calves, equal amounts of milk replacer (8 L/d) in different frequencies (2 times vs. 4 times), no significant differences existed between treatments regarding hunger behaviors, although unrewarded visits were greater for 2x calves[57].

Lying behavior is another behavioral index that is related to calf welfare[58,59]. Calves with restricted milk-fed behaved differently. In contrast, Alimirzaei et al.[60] indicated that calves on an intensified milk-feeding program had increased standing time at the week after weaning when compared to those on a conventional milk-feeding program. Weaning is a challenging process for high milk-fed calves since the dynamic or individual weaning method has been reported for ad libitum-fed calves[61]. On the other hand, in calves with limited access to milk, as a result of restricted energy intake, which reduces animal welfare[54] the immune function may be disturbed. Besides the negative impacts of depressed immune function on mammalians' health and welfare, the dysregulated immune system has been reported related to aggression in humans[62]. Similarly, aggressive animals may show increased levels of several proinflammatory cytokines[62]. Subordinate animals receiving repeated social defeats may have dysregulated immune systems[62]. In dairy cattle models, it has been reported that more excitable cattle have elevated basal levels of catecholamines and glucocorticoids[63]. Accordingly, with reduced immune function in calves with restricted feeding accompanied by environmental stressors, the calves' behavior, performance, and welfare may be affected. More research is needed to determine the role of the milk-feeding system and immune response on neonatal calves' temperament and behavior.

4.2. Forage feeding

In addition to the liquid feed, neonatal calves need solid feeds or concentrates as well as forages for optimal rumen development and growth[64]. The main part of starter feeds and supply, is fermentable carbohydrates needed for developing the rumen epithelium including, cereal grains[65]. However, carbohydrate overload in the rumen can decrease the rumen pH and calf performance[66]. To avoid the adverse effects of low rumen pH on the intake and growth of calves, forage in the calf starter diet can mitigate the negative effects of grain load in the rumen environment[66]. As such, the positive effects of forage provision on rumen pH during pre- and post-weaning periods may be due to the feeding behavior of calves. It is reported that chewing activity (eating plus ruminating) increases when forage is included in the starter diet[67]. Moreover, non-nutritive oral behavior and feed sorting decrease as calves are supplemented by forages[67]. Similarly, a recent finding showed decreased non-nutritive oral behavior in forage-fed calves[63]. The role of forage feeding on dairy calves' chewing activity has also been reported in some studies[68-72.] The importance of ruminating behavior in pre-weaned calves has been demonstrated more recently, with more emphasis on the age at which rumination is initiated. It is believed that age at first rumination is associated with reduced duration of non-nutritive oral behaviors, increased eating time, and feed intake of calves during the first month of life[73,74]. It is important to note that forage particle size may affect the duration of rumination. For calves with longer feeding particle sizes, more time had been observed to ruminate. Generally, forage type and particle size could affect physicochemical properties of forages, influencing calf performance and behavior[68]. Due to the stimulation of chewing by forage feeding, supplementing before weaned calves with various forages may improve rumen digestion and metabolic activity, such as stabilization of the rumen environment, and renewal of rumen contractility, at well above passage rate[75].

5. Disease and calf behavior

Young dairy calves, which are born with an immature immune system, make them susceptible to infectious diseases at an early age[60]. As the mortality rate is high in the pre-weaning period, early identification is critical for saving the sick calves[12,76]. In addition, due to the limited time in caring calves on farm, quick action is vital. Behavioral changes during disease incidence may be a good indicator for early diagnosis and effective treatment of diseases[12]. In general, reduced feeding behavior, activity, and social contact are considered as sickness behavior in

animals[77]. It has been demonstrated that sick calves significantly spent more time lying than healthy calves for about 17.6 ± 0.3 vs. 16.7 ± 0.2 hours, respectively[12]. Additionally, both the activity and feeding behavior of calves followed the same pattern[12] during the days before the peak of the disease. It is described that new technologies measuring the daily behavior of calves can provide useful information for the early diagnosis and treatment of sick calves. To determine a useful indicator of respiratory diseases, the disease was induced by inoculating Mannheimia haemolytica, and physiologic, pathological, and behavioral changes were assessed[78]. The Reduction in activity following the introduction of the disease was noted to be a good indicator for detecting respiratory diseases at an earlier stage, taking into account the total number of steps carried out over 24 hours. In another study conducted to identify early disease signs, Hixson et al.[79] indicated that experimentally infected calves with Mannheimia haemolytica showed decreased feeding, grooming, and social behaviors. Such behaviors could be a useful tool for early diagnosis of respiratory diseases. Moreover, in a recent study concerning relationships between feeding behavior and activity with the recovery status of calves[80], increased feed intake and activity levels were reported for recovered calves from respiratory diseases relative to relapsed calves showing sickness behavior.

In the case of neonatal calf diarrhea (NCD), calves artificially inoculated by rotavirus had a reduced number of lying bouts whereas the duration of lying bouts increased by indicating the clinical signs[81]. Besides lying behavior changes, increased duration of visits to the water trough can be considered a potential indicator of disease in pre-weaned calves[81]. Similarly, in a study conducted to determine the association between NCD and lying behavior, decreased lying time and increased lying bouts were found among sick calves compared with healthy ones. The results of recent studies regarding disease incidence and behavioral changes in pre and post-weaned calves suggest that early detection of diseases may be made possible using of new precision behavior monitoring equipment in calves on farms. More research is needed to understand how behavioral responses can help producers and managers to identify diseases in their early stages.

6. Conclusion

The environment in which calves are raised in can have short- and long-term behavioral and welfare consequences. Since dairy calves are social animals, flexibility when facing new environments or feeds and social skills can be improved by raising them in groups. Early life isolation is a worldwide ordinary management practice that may reduce calf welfare and restrict social skills. However, it is believed that disease transmission could be limited in these housing systems. Recent studies suggest that the health, feed intake, growth, and social behaviors of pre-weaning calves can be improved by group housing. Decisions on isolating or grouping calves in the pre-weaning period depend on farm facilities and management priorities. Calves' behavior and health may also be affected by personality and feeding management. In the case of exploratory calves, growth and nutritional intake may be increased as opposed to fearful calves. Besides personality, it seems that feeding higher amounts of milk and forage in the pre-weaning period provides calf energy and fiber requirements towards growth and development. Behavioral responses can be applied as on-farm tools for the early detection of diseases, such as respiratory diseases and diarrhea. Accordingly, using new precision technologies and recording the daily behavior of calves could provide useful and reliable information for detecting sick calves in groups.

Declarations

Competing interests

The authors have declared that no competing interests exist.

Authors' contributions

The authors contributed to writing the initial manuscript almost equally. Akbar Nikkhah and Masoud Alimirzaei conceptualized the review idea, strategized the topic development, and did the ultimate writing and editing. The final manuscript was checked by all authors.

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Data from the study are available according to a reasonable request.

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The authors have made necessary ethical considerations (e.g., plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy).

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