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UNIVERSIDADE ESTADUAL PAULISTA
FACULDADE DE MEDICINA VETERINÁRIA E ZOOTECNIA
CAMPUS DE BOTUCATU

EFFECT OF ENVIRONMENTAL ENRICHMENT ON BEHAVIOR AND PERFORMANCE OF DAIRY CALVES

JOÃO PEDRO DONADIO DA SILVA PEREIRA

Dissertação apresentada ao Programa de Pós-graduação em Zootecnia como parte das exigências para obtenção do título de Mestre em Zootecnia

BOTUCATU – SP
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Orientador: Prof. Dr. Matheus Deniz
Co-orientadoras: Dra. Karolini Tenffen De-Sousa
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ATESTADO DE APROVAÇÃO - DEFESA

Atestamos que **JOÃO PEDRO DONADIO DA SILVA PEREIRA**, RA nº: ZNP230065, RG nº 525848757, expedido pela, defendeu, no dia 28/02/2025, a dissertação intitulada **EFFECT OF ENVIRONMENTAL ENRICHMENT ON BEHAVIOR AND PERFORMANCE OF DAIRY CALVES**, junto ao Programa de Pós Graduação em Zootecnia, Curso de Mestrado Acadêmico, tendo sido 'APROVADO'.

Atestamos ainda que a obtenção do título dependerá de homologação pelo Órgão Colegiado competente.

Botucatu, 28 de fevereiro de 2025

Cláudia Cristina Meraci
Assistente Administrativo
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RESUMO GERAL

As práticas convencionais de criação de bezerros leiteiros, como o alojamento individual em ambientes com poucos estímulos, são amplamente adotadas, mas seus impactos negativos no bem-estar dos animais têm sido alvo de críticas da sociedade. Essas práticas restringem comportamentos naturais essenciais para o desenvolvimento dos bezerros, como o contato social, exploração e a sucção, podendo resultar em estresse e frustração. O enriquecimento ambiental envolve modificações que buscam aumentar a relevância biológica do ambiente de criação. Este estudo teve como objetivo avaliar os efeitos do enriquecimento ambiental – por meio do alojamento em grupo durante o pré-desmame, do enriquecimento físico e da oferta de água por bicos – no comportamento, saúde e desempenho de bezerros leiteiros. Primeiramente, realizamos uma revisão sistemática com abordagem meta-analítica de estudos que compararam a criação de bezerros leiteiros em pares ou grupos com a criação individual. Os resultados indicaram que o alojamento precoce (< 14 dias de idade) em grupo traz benefícios significativos, como maior ganho de peso e consumo de concentrado, além de favorecer comportamentos ativos, como alimentação e brincadeira, e reduzir comportamentos de autolimpeza. Na segunda parte, uma revisão sistemática foi conduzida para compilar estudos sobre enriquecimento físico para bezerros leiteiros, como o aumento do espaço disponível, acesso a áreas externas e adição de objetos no ambiente de criação. As práticas de enriquecimento físico mostraram-se eficazes em elevar os níveis de atividade, promover comportamentos exploratórios e reduzir comportamentos anormais, como a mamada cruzada. Por fim, conduzimos um experimento para avaliar o impacto do enriquecimento nutricional, fornecendo água por bicos, no comportamento de bezerros alojados em grupo à pasto. Nossos resultados sugerem que a mudança na oferta de água influencia a atividade dos bezerros ao longo do tempo, alterando o padrão de ingestão de água, com maior consumo durante a noite. Observamos também que a ausência de estímulo para a sucção, ao utilizar baldes abertos para a oferta de água, contribuiu para o aumento da mamada cruzada. Em síntese, os estudos destacam a importância de modificar o ambiente de criação para atender às necessidades comportamentais dos bezerros, evidenciando os benefícios do alojamento em grupo, do enriquecimento físico e da oferta de estímulos para a sucção na melhoria do bem-estar desses animais. É fundamental que as práticas de manejo levem em conta esses aspectos para promover a saúde e o desenvolvimento adequado dos bezerros, contribuindo, assim, para a sustentabilidade das fazendas leiteiras.

Palavras-chave: bem-estar animal; bovinocultura leiteira; etologia aplicada; experiências positivas; produção animal; resiliência.

ABSTRACT

Conventional dairy calf-rearing practices, such as individual housing in low-stimulation environments, are widely used but have increasingly come under societal scrutiny due to their negative impact on animal welfare. These practices restrict natural behaviors essential for calf development, including social contact, exploration, and sucking, which can lead to stress and frustration. Environmental enrichment includes modifications aimed at enhancing the biological relevance of the rearing environment. This study sought to evaluate the effects of environmental enrichment—through group housing during the pre-weaning phase, physical enrichment, and water provision through teats—on the behavior, health, and performance of dairy calves. First, we conducted a systematic review and meta-analysis of studies comparing pair or group housing for dairy calves with individual housing. Results showed that early group housing provides significant benefits, such as increased weight gain and concentrate intake, as well as promoting active behaviors, like feeding and play, and reducing self-cleaning behaviors. In the second part, a systematic review compiled studies on physical enrichment for dairy calves, such as increased available space, access to outdoor areas, and the addition of objects to the environment. Physical enrichment practices were found to effectively increase activity levels, encourage exploratory behaviors, and reduce abnormal behaviors, such as cross-sucking. Finally, we conducted an experiment to assess the impact of nutritional enrichment, by providing water through teats, on the behavior of group-housed and pasture-raised calves. Our results suggest that changing the method of water provision influences calf activity patterns over time, altering water intake with increased consumption at night. We also observed that the absence of a sucking stimulus, when open buckets were used for water provision, contributed to an increase in cross-sucking behavior. In summary, these studies emphasize the importance of modifying the rearing environment to meet calves' behavioral needs, highlighting the benefits of group housing, physical enrichment, and providing sucking stimuli to improve calf welfare. It is essential for management practices to consider these factors to support calf health and development, thereby contributing to the sustainability of dairy farms.

Keywords: animal production; animal welfare; applied ethology; dairy cattle; positive experiences; resilience.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ADG	Average daily gain
AGP	Alpha-1-Acid Glycoprotein
BHB	Beta-Hydroxybutyrate
BW	Body weight
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CI	Confidence interval
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico
FMVZ	Faculdade de Medicina Veterinária e Zootecnia
GLMM	General linear mixed model
ID	Identification
IFN-γ	Interferon Gamma
IgG	Immunoglobulin G
NA	Not applicable
NEFA	Non-Esterified Fatty Acids
REML	Restricted Maximum Likelihood Estimate
SMD	Standardized mean difference
THI	Temperature-Humidity Index
UNESP	Universidade Estadual Paulista
WT	Water trough
WMD	Weighted mean difference

SUMMARY

INTRODUCTION

In commercial dairy calf rearing, conventional practices such as individual housing, social isolation, early weaning, and separation from the mother often compromise calf welfare (COSTA et al., 2019; MEE, 2013; VON KEYSERLINGK et al., 2009). Despite being widely adopted, these practices are increasingly criticized for their adverse effects on calf welfare (PERTTU; VENTURA; ENDRES, 2020; PLACZEK; CHRISTOPH-SCHULZ; BARTH, 2021; SIROVICA et al., 2022). Calves in conventional systems may experience stress and frustration due to a lack of stimuli, such as social isolation, restricted movement, and limited opportunities to express natural behaviors (HULBERT; MOISÁ, 2016; WHALIN; WEARY; VON KEYSERLINGK, 2021). The ability to express species-specific natural behaviors is crucial for animal welfare, as it reflects their capacity to adapt and cope with environmental challenges (BROOM, 1986). When these behaviors are disrupted, it may indicate that the animal is struggling to meet its biological and psychological needs (WEINER, 1992).

Stress plays a critical role in influencing behavior (MOBERG, 2000), particularly through activation of the hypothalamic-pituitary-adrenal axis, which triggers the release of glucocorticoids such as cortisol (TSIGOS; CHROUSOS, 2002). This stress response is vital for short-term survival, enabling the animal to deal with immediate threats or challenges. However, when stress becomes chronic or recurrent (distress), it can have detrimental effects on the animal's health, growth, and productivity (GRANDIN; DEESING, 2002; UNDERWOOD, 2002). In dairy calves, stressors such as early maternal separation, poor housing conditions, restricted social interactions, and inadequate nutrition can disrupt biological functions, making calves more susceptible to disease, impairing growth, and altering metabolic processes (STAFFORD; MELLOR, 2011; WEARY; JASPER; HÖTZEL, 2008). While cortisol levels, measured in serum, plasma, saliva, feces, urine, or hair, are commonly used to assess stress (HEIMBÜRGE; KANITZ; OTTEN, 2019; MÖSTL; PALME, 2002), they offer only part of the picture. Changes in behavior, such as increased vocalizations, restlessness, and reduced play, are important factors that should be considered to provides a more comprehensive view of the animal's ability to cope with stress (ALADOS; ESCOS; EMLEN, 1996; RUTHERFORD et al., 2004).

Natural behaviors are essential indicators of an animal's needs and its ability to cope with its environment (FRASER et al., 1997). These behaviors have evolved to fulfill biological functions related to survival, social bonding, and overall well-being. Recognizing the origins and motivations behind such behaviors helps inform management practices that minimize the

negative impacts of confinement and improve animal welfare (NEWBERRY, 1995). In dairy calves, behaviors such as social contact, scratching, and suckling are not only instinctive but also highly motivated, meaning that calves actively seek opportunities to express them (DE PASSILLÉ, 2001; EDE; WEARY; VON KEYSERLINGK, 2022; MCCONNACHIE et al., 2018). When these behaviors are restricted, such as through individual housing or bucket feeding, calves may develop signs of frustration and engage in abnormal behaviors, including excessive licking, cross-sucking, or stereotypies (JENSEN; BUDDE, 2006; VEISSIER; CARÉ; POMIÈS, 2013). Understanding these biological drives is crucial for designing housing and management systems that allow for the expression of natural behaviors, ultimately supporting healthier physical and psychological development in dairy calves.

Natural behaviors can be encouraged by adopting environmental enrichment, which involves modifications to enhance the biological relevance of captive animals' environment (NEWBERRY, 1995) and contributes to positive animal welfare (RAULT et al., 2025). Environmental enrichment is categorized into sensory, occupational (cognitive), nutritional, social, and physical dimensions (BLOOMSMITH; BRENT; SCHAPIRO, 1991). This concept has been widely applied in captive animal management, from zoo animals to farm livestock (CARLSTEAD; SHEPHERDSON, 2000; HERRON; BUFFINGTON, 2012; MAPLE; PERDUE, 2013; VAN DE WEERD; DAY, 2009). There is increasing interest in environmental enrichment for dairy calves. However, research on this topic remains limited and dispersed (MANDEL et al., 2016). For example, social contact plays a crucial role in the emotional and cognitive development of calves (BERTELSEN; JENSEN, 2019). The stress caused by social isolation makes calves more fearful than those with social contact (CREEL; ALBRIGHT, 1988; GAILLARD et al., 2014). On the other hand, social contact allows calves to engage in natural behaviors like play, running, and grooming, which are essential for their social and physical development (LI et al., 2020; MINTLINE et al., 2013). Group housing has been widely studied to understand the role of social interactions in calf development, as these interactions promote emotional and cognitive growth, reduce stress, and enhance resilience (BREEN et al., 2023; MALÁ et al., 2023; ZHANG; JUNIPER; MEAGHER, 2021).

Also, enriching the physical environment—by increasing space, providing access to outdoor areas, or adding items like grooming brushes or objects for exploration—can significantly improve calf welfare (CALVO-LORENZO et al., 2017; SINNOTT et al., 2022; SUTHERLAND; WORTH; STEWART, 2014; ZHANG; JUNIPER; MEAGHER, 2022). Outdoor calf-rearing systems have been shown to offer benefits, including improved health outcomes (LORENZ et al., 2011; WÓJCIK; NAŁĘCZ-TARWACKA; GOŁĘBIEWSKI, 2013)

and reduced fearfulness (FIELD et al., 2024), compared to conventional indoor settings. Physical changes to calves' environment can boost activity levels (LI et al., 2020), encouraging play and exploratory behaviors, and reduce abnormal behaviors such as non-nutritive oral behaviors (ZHANG; JUNIPER; MEAGHER, 2021). For environmental enrichment to be effective, however, it must provide stimuli from which animals can acquire information, pleasure, and enhance behavioral adaptability, in other words, improve animal's welfare (VEISSIER et al., 2024). This growing interest in environmental enrichment for dairy calves highlights the need for a systematic and comprehensive understanding of how such strategies can enhance calf welfare.

Non-nutritive behaviors in calves, such as cross-sucking and other oral stereotypies, are usually related to negative emotional states (DE PASSILLÉ; RUSHEN; JANZEN, 1997; LIDFORS, 1993) and animals can hurt themselves and others performing this abnormal behavior (LALANDE; BEAUCHEMIN; H. FAHMY, 1979). Using nipple-based feeders instead of open buckets for milk feeding has been shown to reduce the frequency of cross-sucking, rewarding them with milk when they perform this behavior (JENSEN; BUDDE, 2006; REIPURTH et al., 2020). For instance, many other modifications to rearing environments and management strategies have been explored to reduce cross-sucking behavior (WELK; OTTEN; JENSEN, 2023). Providing a dry teat (JENSEN, 2003; UDE; GEORG; SCHWALM, 2011), using a nursing cow (BERTELSEN; JENSEN, 2023), and providing *ad libitum* milk (DE PAULA VIEIRA et al., 2008; MILLER-CUSHON et al., 2013; TODD et al., 2018) are strategies that encourage natural suckling behaviors and help reduce cross-sucking. Nevertheless, there are limitations to implementing these practices in dairy farm settings, and there is a need for alternative approaches to support calves' natural suckling behaviors.

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Final considerations and implications

Our findings underscore the benefits of early group housing, physical enrichment, and nipple provision in supporting dairy calves' growth, health, and natural active behaviors. Together, these studies show that well-designed enrichment positively impacts calf behavior and welfare, advocating for a comprehensive approach to calf-rearing those addresses both physical and social needs. Effective management practices that meet calves' natural motivations contribute to healthier development and support sustainable dairy farming. In this thesis, environmental enrichment is defined as modifications that improve biological functioning, yet for calves, some of these practices serve to fulfill basic needs. Calves are strongly motivated to engage in behaviors like social interaction, suckling, and grazing; however, barren environments (usually adopted in commercial dairy farms) often lack the necessary stimuli for these behaviors, leading to the development of abnormal behaviors. The dairy industry should shift toward establishing baseline environments that inherently fulfill calves' basic needs, such as providing social contact, supporting natural suckling behavior, and ensuring essential welfare standards. With these foundational needs met, environmental enrichment can then go beyond simply addressing innate behaviors, focusing instead on additional stimulation that fosters exploration and enhances welfare.