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Developing a practical tool to assess hunger in Norwegian red calves

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Abstract

Restrictive feeding practices are commonly employed for dairy calves, but it is imperative to recognize that hunger adversely affects the health and well-being of these young animals. This research aims to develop a practical tool for evaluating hunger in dairy calves. I predicted that the finger sucking test could be used to assess hunger in dairy calves. During the test, I predicted that calves fed restrictive amounts of milk would have a shorter latency to suck on human fingers compared to ad libitum fed calves and before feeding calves will orally manipulate my finger more than after feeding regardless of treatment. Twelve Norwegian Red calves (birth weight: 37.0 ± 3.8 kg) were used in a larger experiment from birth to 12 weeks of age. The specific experiment involving these calves was initiated at approximately 3 weeks of age (24 ± 4 days). Calves were enrolled in 2 treatments, where six calves housed in enriched group (4 females, 2 males) provided *ad libitum* 4 times per day and six calves housed individually (4 females, 2 males) were fed 7L of milk divided into 3 times per day. Behavioral distinctions were observed between the Enriched and Minimal treatment groups. Calves in the Enriched treatment exhibited more individual variation before feeding compared to minimal group calves, ranging from 0 to 50%. The median sucking percentage to suck finger for enriched group calves were 27.5%. In contrast, calves in the Minimal group displayed a narrower range of sucking behavior, with observations ranging from 0 to 25% and a median of 3.12%. In addition, among the 12 observed calves, a total of 8 calves displayed finger-sucking behavior before feeding, with 5 calves in the enriched group and 3 calves in the minimal group. The findings suggest that group housing may be associated with heightened finger-sucking motivation, in contrast to individually housed calves, potentially contributing to reduced finger sucking behavior. It's important to note that several management differences existed between the groups, and while a 'restricted' milk allowance appeared to have limited impact on finger-sucking behavior, it is acknowledged that other factors could have influenced these outcomes.

Contents

1 Introduction

1.1 Animal welfare

1.11 Definition of Animal Welfare

Animal welfare science is inherently linked to ethical considerations for animals and several different frameworks have been developed to conceptualize the topic (e.g.,(Brambell, 1965; Broom, 1991; Fraser et al., 1997)). Perhaps the first animal framework was the five freedoms developed by the Brambell (1965).The Five Freedoms focus largely on freedoms from negative feeling, such as hunger, discomfort, and pain (Brambell, 1965). The united kingdom farm animal welfare council codified the Brambell's report in 1979 (FAWC, 1993; Elischer, 2019) (see Table 1). Since this early framework, other scientists have refined the definition of animal welfare to incorporate more factors an animals may experience. Broom (1991) concluded that animals may react differently to a single environment, and how they react mat be indicative of their welfare. Duncan (2005) found that animal welfare is related to their feelings such as frustration, hunger, pain and thirst. Mellor described yet another framework where Five Domains model, including health condition, nutrition, environment, behavior and mental state, was used as an integrated evaluation system to improve animal welfare environment (i.e., worked as a reference subject in experiments) (Mellor and Reid, 1994). Finally, Fraser et al. (1997) framework highlights three overlapping areas of concern: biological functioning (i.e., in the growth, regular function of biological, adequate health and actions), natural living (i.e., keep natural activities), and affective states (i.e., minimize of emotion affect). These authors suggest that improvements to an animal's care must incorporate all three of these concerns. I will use Fraser's framework as a guiding structure to shape my research questions and interpretations in my thesis.

Table 1 The Five Freedoms of the Farm Animal Welfare Council revised in 1979.

NO	Principle	Application
1	**Freedom from hunger and thirst:**	Ready access to fresh water and a diet to maintain full health and vigor
2	**Freedom from discomfort:**	An appropriate environment including shelter and a comfortable resting area
3	**Freedom from pain, injury or disease:**	Prevention of disease and injury, and rapid diagnosis and treatment when needed
4	**Freedom to express normal behavior:**	Sufficient space, proper facilities, and appropriate social environment
5	**Freedom from fear and distress:**	Conditions and handling that avoid mental suffering

1.12 Social Concern

Animal welfare science developed due to societal concerns for the care of animals (Szucs et al., 2012). Just as there are many scientific definitions of animal welfare, different members of society value components of animal welfare differently. One study concluded that farmers are very helpful in implementing good animal care (Balzani and Hanlon, 2020). Individual farmer knowledge and attitudes may also affect how they view and care for their animals. For example, one survey found that more knowledgeable farmers were able to treat diseases efficiently, and farmers with more positive attitudes towards animals may provide an excellent oversight that affect optimal output in dairy animals (F.Adler, 2019). Veterinarians place value on the health of animals such that they want farmers to provide appropriate care and seek timely treatment when an animal is unwell (Wensley, 2008). Additionally, an investigation was conducted among veterinarian students to assess their opinions on animal welfare with regards to sensitivity and cognition toward animals. The study's findings revealed that female students exhibited higher levels of empathy compared to their male counterparts (Paul and Podberscek, 2000).

The public has feelings and responsibilities toward animal welfare, but it mostly associated with moral basis and concern with disease that affect human health (Broom, 2010). Public opinion regarding the ethical treatment of animals exhibits variability across different nations. For instance, the acceptance of animal experimentation for medical purposes is notably pronounced in Japan (Uchikoshi and Kasai, 2019). In China, heightened concern arises over the utilization of animals in contexts such as human adornments, including leather goods and cosmetics (Davey and Wu, 2007). In northern European nations, the promotion of animal-derived products often intertwines with moral principles and emphasizes the concept of sustainability, thereby conveying an implicit assurance of meticulous animal care (Borkfelt et al., 2015).

1.2 Dairy calf management

1.21 Calf housing and Feeding

Dairy calves in most farms from around the world are directly separated from the cow after birth (Lidfors, 1996). In the USA, over 70 % of pre-weaned dairy calves are housed in hutches individually (USDA, 2016). Similarly, 80 % of heifer calves in Brazil are housed in indoor pens (Hötzel et al., 2014). In Norway, group housing of calves had been implemented in most farms (Johnsen et al., 2021) and the legislation from the Ministry of agriculture and food permits calves can be placed in single pen until they reach the age of eight weeks (2004). Though common practice, raising young calves in isolation may lead to some challenges. For example, Costa et al. (2016) found that individually housed calves had lower average daily gains compared to group housed calves. Perhaps the group housed calves were socially stimulated to eat concentrate (Warnick et al., 1977; Jensen et al., 2015). Chua et al. (2002) discovered that single housing offers a limited space for exercise in contrast to group housing, where calves engage in movement and social interactions. Costa et al. (2016) demonstrated that solitary housing can exert adverse effects on behavioral development and present challenges in adapting to an aberrant environment and calves may experience cognitive issues in their later life stages compared to those raised in group housing systems.

Calves are usually fed milk by bucket or a bottle (Medrano-Galarza et al., 2017). In the natural system calves may suckle a high milk allowance from their mother 6-8 times per day (PAWS, 2021); indeed, when provided ad libitum milk, calves may consume average 14.5 L/d (Josera, 2018). The milk feeding regimes for most dairy calves are quite different. For example, In Brazil, normal milk allowance for heifers are 4L/d in the first two months (Hötzel et al., 2014). Automatic feeding systems may allow farmers to easily provide a higher milk allowance to individual calves (Janzekovic et al., 2011). The global agreement for feeding specific amount of milk in individual hutch is a total of 10 percent of the calf’s body weight (Appleby et al., 2001), it has increased to 20 percent (Health et al., 2023).The recommended milk intake for calves was six liters per day, but it has been adjusted now to eight liters per day (Overrein et al., 2015). Norwegian calves are often fed an average of 7-8L milk/d (Johnsen et al., 2021).

1.22 management challenges

Unfortunately, the mortality rate among group-housed calves has been reported to be higher during the first month of their lives compared to calves housed individually in single pens (Gulliksen et al., 2009). This disparity is often attributed to poor management practices (Relić et al., 2020) and the increased risk of infectious diseases, such as pneumonia and diarrhea (Cho and Yoon, 2014). Godden (2008) found that proper colostrum management plays a crucial role in influencing the health and survival of calves.

Furthermore, the housing environment, including factors like temperature and ventilation, has been identified as a critical aspect of calf management (AHDB, 2017). Indication that proper housing conditions are essential for creating a conducive and healthy environment for calves, which can significantly impact their overall well-being and survival rates.

1.3 Welfare measurement

Animal welfare is a crucial dimension that can be evaluated by considering an individual animal's state (Broom, 1988). Various methods exist for measuring welfare, each yielding different responses when applied to animals. Two commonly utilized approaches are animal-based indicators, which involve assessing changes in the animals' bodies, and resource-based indicators, which examine environmental changes (Salas and Manteca, 2016).

The physical appearance of animals, such as hair condition, feather condition, and body conditions, can serve as indicators for measuring welfare (Salas and Manteca, 2016). Keeling et al. (2011) emphasized the importance of considering an animal's emotions, as they are closely related to its overall health, making attentive observation a crucial aspect of welfare assessment.

Since the 1990s, an increasing emphasis has been placed on resource-based indicators within the field of animal welfare. Rushen and Passillé (1992) found that housing quality would impact the animal’s welfare. Similarly, de Wilt (1985) revealed that the size of the living area can influence normal behaviors such as grooming activity and resting, especially when too many calves are housed in one pen.

Overall, it is essential to consider both animal-based and resource-based indicators to gain a comprehensive understanding of animal welfare. By combining these methods, researchers can enhance their ability to assess and improve the well-being of animals in various settings.

1.4 Hunger

Calves are often fed restricted food in most farms (D'Eath et al., 2009). According to Stunkard (1975), hunger is a sensory awareness combined with the motivation to obtain food, regulated by neural systems. Studies conducted by Hammell et al. (1988) discovered that calves exhibit a strong inclination towards performing sucking behavior when consuming milk. Calves that are provided with limited milk allowances have been observed to engage in more aggressive and energetic sucking behaviors (De Paula Vieira et al., 2008), suggesting a potential association with hunger. Nevertheless, most of the welfare research has primarily focused on the animals' health and productivity, making the measurement of hunger more challenging due to the scarcity of validated methods for assessing this feeling (Lecorps et al., 2023).

Recent efforts have been made to explore hunger in dairy calves. Lecorps et al. (2023) investigated the impact of reducing the milk allowance from 12 to 6 liters per day and found negative effects on the cognitive function and hunger sensation of the calves.

Additionally, a study by (Jensen et al., 1998) utilizing an automatic milk feeder revealed that calves provided with a lower milk allowance made more unrewarded visits to the milk feeder compared to those with a higher allowance.

Cross-sucking behavior, a non-nutritive sucking response to perceived milk supply reduction, has been associated with milk allowance. Higher milk volumes have been shown to decrease cross-sucking, as indicated by studies by De Passillé (2001), Jensen (2003), Lidfors (1993).

Furthermore, the expression of motivation to suck in calves has been associated with vocalization. Studies have shown that calves increase vocalization, particularly before milk feeding, indicating a potential link between vocal motivation and hunger (Thomas et al., 2001).

1.5 Knowledge Gaps

From the literature review, there are certain knowledge gaps in calf hunger. Other studies investigating hunger in calves have looked at amount drunk/eaten, number of times visits to the feeder, time spent around feeder. However, a crucial gap remains in our understanding of potential indicators, particularly behavioral responses, that can reliably gauge hunger in calves experiencing different milk allowances. The primary objective is to devise a robust hunger assessment tool that effectively quantifies and evaluates hunger states.

Rationale for a New Hunger Test:

Several factors underscore the necessity for a new hunger test:

1. Behavioral Insight: Introducing a behavioral indicator, such as finger sucking, can potentially provide a more direct window into calf hunger.
2. Practicality and Accessibility: A hunger test that incorporates observable behaviors like finger sucking offers a practical advantage. This method can be readily implemented on farms, facilitating routine hunger assessment without the need for specialized equipment or extensive training.
3. Early Detection and Management: The potential of a new hunger test lies in its capacity for early hunger detection. Timely recognition of hunger can allow

auditors to make informed adjustments to feeding practices, optimizing calf health and growth performance.

1.6 Aim of the thesis

The aim of the thesis was to try to develop and validate a finger sucking test as an easy on-farm assessment of hunger in dairy calves.

1.7 Hypotheses

Following predictions were tested in the study:

Prediction 1: The finger sucking test is a valid and reliable method for assessing hunger in dairy calves.

Prediction 2: Calves fed restrictive amounts of milk have a shorter latency to suck on human fingers compared to ad libitum fed calves.

Prediction 3: Before feeding calves will orally manipulate my finger more than after feeding.

2 Methods and Materials

This experiment was conducted as part of a larger study, CalfComfort (Research Council Norway, project no 325663) led by the Norwegian Veterinary Institute. The data used for this thesis were collected in February 2023 at the Norwegian University of Life Science (NMBU) Livestock Production Research Centre (Senter for husdyrforsøk SHF) in Ås, Norway. The calves were kept and cared for according to the Norwegian animal welfare rules and the directive on keeping of cattle. The clinical trial was approved by Forsøksdyrforvaltningens tilsvns- og søknadssystem (FOTS), case no 22/112522.

2.1 Housing and Animal management

Twelve Norwegian Red calves (birth weight: 37.0 ± 3.8 kg) were used in a larger experiment from birth to 12 weeks of age. The calves in this thesis were from two treatments: minimal housing (4 females, 2 males), and enriched housing (4 females, 2 males). Each group was filled in chronological order according to calf birthdate to minimize age differences within a group. All calves were separated from their mothers within 30 min of birth, bottle-fed or tubed 4 L of colostrum from their mothers within 6 h of birth, and had *ad libitum* access to hay, water, concentrates and silage. When they were 24-48 h old, the calves underwent a health check using the Wisconsin Calf Health Scoring App. When the calves reached approximately 3 weeks of age (24 ± 4 days), observations were conducted for the enriched group calves on weekdays (Monday to Friday), and for the minimal group calves on weekdays (Monday to Thursday). The data presented in this thesis were collected during these designated observation periods.

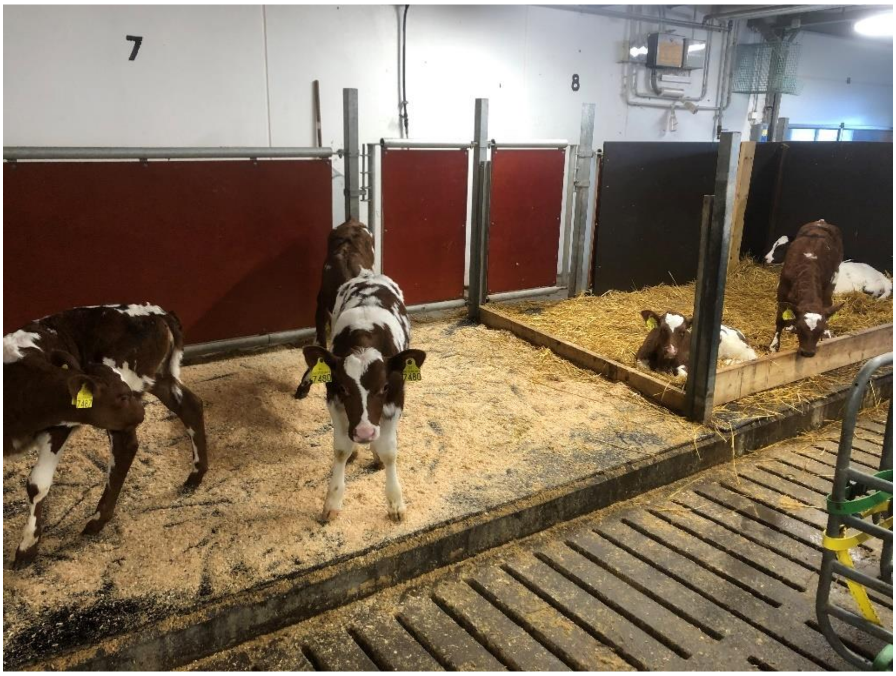
Calves that had diarrhea, poor appetite or an attitude score above 1 were excluded from the experiment. Twins and calves from a difficult birth were not included in the experiment. Three calves were excluded from the experiment due to failing to meet inclusion criteria (2), or difficult birth (1). A trained observer examined the calves twice per week using the Wisconsin Calf Health Scorer App. Calves experiencing diarrhea were given oral electrolytes once per day following farm protocols.

2.1.1 Enriched calves

After separation, calves who were assigned to the Enriched treatment were moved to a pen with a total of 6 calves. The pen (23.1 m^2) consisted of two lying areas (one with a rubber mattress covered with a deep layer of straw and one with a rubber mattress lightly covered with sawdust), 2 stationary brushes attached to the side walls, and rubber slatted floor (Picture 1). The pen was scraped daily, and fresh straw added twice per week. The Calves were given ad libitum milk from 2 milk bars with 5 teats 4 hours per day at approximately 06:00 – 07:00, 10:00 – 11:00, 14:00 – 15:00 and 19:00 – 20:00. Milk feeders were checked throughout the hour, and milk was added such that the milk bar was never empty. The calves were fed *ad libitum* concentrates from automatic feeders, hay and silage on a feeding table, and water from a water bowl.

2.1.2 Minimal calves

After separation from the cow, calves who were assigned to the Minimal treatment were moved to individual pens (2.4m^2) bedded with straw, and heat lamps stationed over-head (Picture 2). Pens were cleaned twice per week. Individual pens were divided by 3 solid walls. Calves had visual and tactile contact with neighboring calves through the front gate of their pen. The calves were fed 7 L of milk per day divided into 3 feedings at approximately 06:00, 12:00 and 19:00 from a teat bucket. Each calf had a hay rack filled with hay and silage, a water bowl, and a concentrate bowl.



Picture 1: Six Norwegian red calves housed in enriched group.

Picture 2: Six Norwegian red calves housed in single pen / minimal group.

2.2 Behavioral Observations

The enriched group was observed for a total of 5 days, both before and after feeding, while the minimal group was observed for 4 days, both before and after feeding. This period of observation spanned a total of 9 days. Additionally, all calves were subjected to finger-sucking behavior tests for 60 seconds, 30 minutes prior to milk feeding. Subsequently, a second test session was conducted after the last group was tested. Furthermore, two additional testing sessions were completed, each commencing 30 minutes following milk feeding. All calves were tested one at a time and data was recorded by an assistant (across the experiment 4 people aided with data collection by recording data and distracting non-focal calves and did all the testing and recording data by myself in the minimal experiment). The observer approached the calf starting 2 meters away and approached at approximately 1 step per second with the arm outstretched while looking at the nose of the calf. The approach stopped when the hand was 20 cm in front of the calf's mouth. From this moment, each calf was given up to 60 seconds to suck on the primary observer's finger. Any interruption by other calves marked as interrupted (INT). The identity of the calves performing finger sucking and oral manipulation is presented in Table 2. After each of the 6 calves had sucked the primary observer's finger or had been given 60 seconds, the test was repeated with calves tested in the same order. All calves will function as its own control and hence be tested before and after feedings at 10:00 and 14:00 feeding time. Scoring sheet with predefined testing order based on randomization of the ear tag numbers.

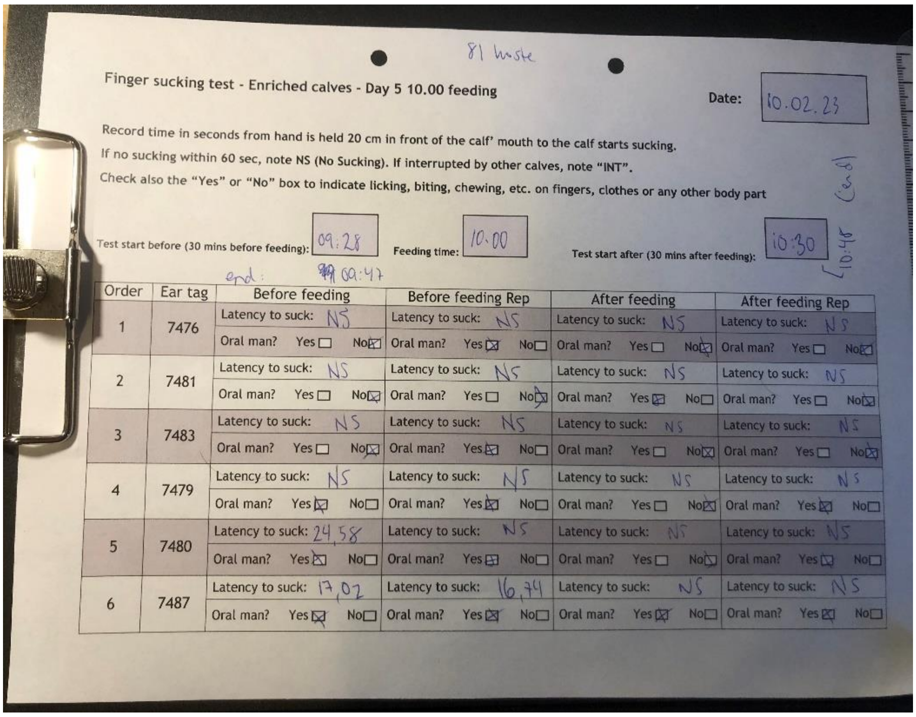
Table 2 Ethogram of calf with finger test.

Variable [1]	**Description**
Oral manipulation	Calves are exhibiting behaviors such as touching and licking of fingers.
Valid fingers sucking	Calves are exhibiting one of below behaviors: 1. Jaw movement with finger in mouth. 2. Feeling vacuum/sucking and sucking sound. 3. Tongue encircling parts or entire fingers.

[1] Data must be collected within 60 seconds

2.3 Data Collection

Testing data were written down directly to scoring sheet (Picture 3), and then entered into a Microsoft Excel spreadsheet for further analysis.



81 waste

Finger sucking test - Enriched calves - Day 5 10.00 feeding

Date: 10.02.23

Record time in seconds from hand is held 20 cm in front of the calf' mouth to the calf starts sucking.
If no sucking within 60 sec, note NS (No Sucking). If interrupted by other calves, note "INT".
Check also the "Yes" or "No" box to indicate licking, biting, chewing, etc. on fingers, clothes or any other body part

Test start before (30 mins before feeding): 09:28 end: 09:47 Feeding time: 10.00 Test start after (30 mins after feeding): 10:30

Order	Ear tag	Before feeding	Before feeding Rep	After feeding	After feeding Rep
1	7476	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☐ No ☒
2	7481	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☐ No ☒
3	7483	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☐ No ☒
4	7479	Latency to suck: NS Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☒ No ☐
5	7480	Latency to suck: 24,58 Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☐ No ☒	Latency to suck: NS Oral man? Yes ☒ No ☐
6	7487	Latency to suck: 17,02 Oral man? Yes ☒ No ☐	Latency to suck: 16,74 Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☒ No ☐	Latency to suck: NS Oral man? Yes ☒ No ☐

Picture 3: One of collected data into Scoring sheet.

2.4 Data Analysis

Basic data analysis was conducted using Microsoft excel (Version 2306, Microsoft 365) to calculate average latency and sucking percentage. Subsequent analyses were performed in R studio version 2023.06.0+421(Team, 2021) utilizing packages such as readxl (Bryan, 2023), tidyverse (Wickham, 2019) , ggplot2 (Wickham, 2016) and dplyr (Vaughan, 2023). By analyzing data in R studio, the results were presented as box plots.

Visualizations began with histograms in R studio to uncover data patterns. Each calf contributed two observations before and after feeding, resulting in a total of 24 observations. Individual data points were visualized for each testing day, revealing consistent patterns across treatment groups. The process of visualizing individual data points for each testing day and observing consistent patterns across treatment groups facilitated the transformation of data into two lines: one representing calf behavior before feeding and another after feeding.

Notably, numeric data pertaining to calf latency to suck finger within 60 seconds was selectively extracted from instances where calves exhibited finger-sucking behavior. Given the observed data correlation of finger sucking and latency, a calf-level analysis approach was adopted, leading to results that offer insight into calf behavior patterns.

3 Results

3.1 Finger sucking

The box plots depict the distribution of finger-sucking behavior across test sessions, reflecting the percentage of sessions in which a calf chose to suck my finger within each treatment group (Figure1). Calves in the Enriched treatment exhibited a wider range of variation compared to the Minimal group calves, ranging from 0 to 50 percent. The median sucking percentage for enriched group calves were 27.5 percent. In contrast, calves in the Minimal group showed less variability in sucking behavior compared to the Enriched treatment, ranging from 0 to 25 percent, with a median of 3.12 percent. For the After feeding, both Enriched and Minimal treatments resulted in minimal sucking behavior, with all calves showing a sucking percentage of 0 percent, except one calf from minimal group showed sucking behavior. This indicates that after feeding condition led to reduced finger-sucking behavior, regardless of the treatment. In addition , across all the tests 12 observed calves, a total of 8 calves did finger-sucking behavior before feeding, with 5 calves in the enriched group and 3 calves in the minimal group.

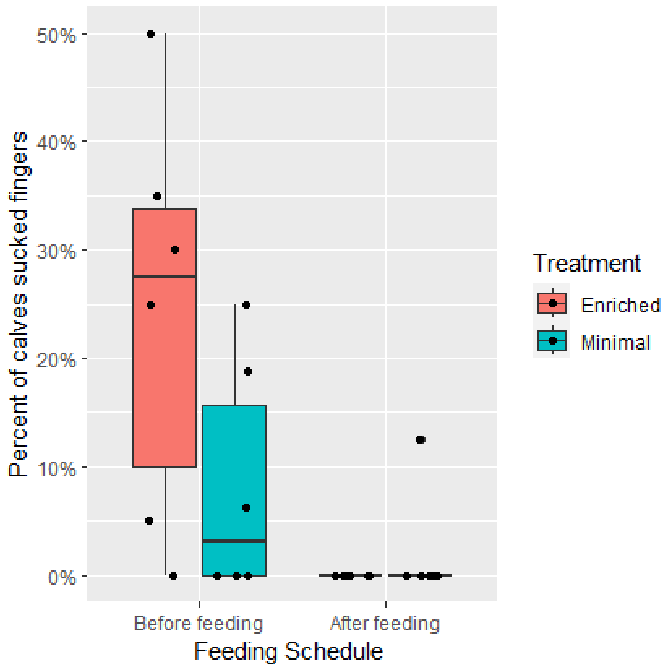


Figure 1 Showing the finger sucking percentage of each calf in the before feeding and after feeding.

3.2 latency

The box plot (Figure 2) displayed the average latency of calves that sucked my fingers within 60 seconds from two treatments across all tests. The average latency to suck fingers mostly occurred before feeding for both enriched (median value of 18.8 seconds) and minimal calves (median value of 23.8 seconds). However, for the minimal group, there is only one data point available (one calf) for after feeding, which is highlighted in red, indicating an average latency of 21.3 seconds.

Given that eight out of the twelve calves engaged in finger-sucking behavior, the resulting dataset comprises eight data points, each representing the average latency. Among these, calves had *ad libitum* access correspond five data points from the enriched group before feeding, while the calves had restricted milk allowance were remaining three pertain from the minimal group.

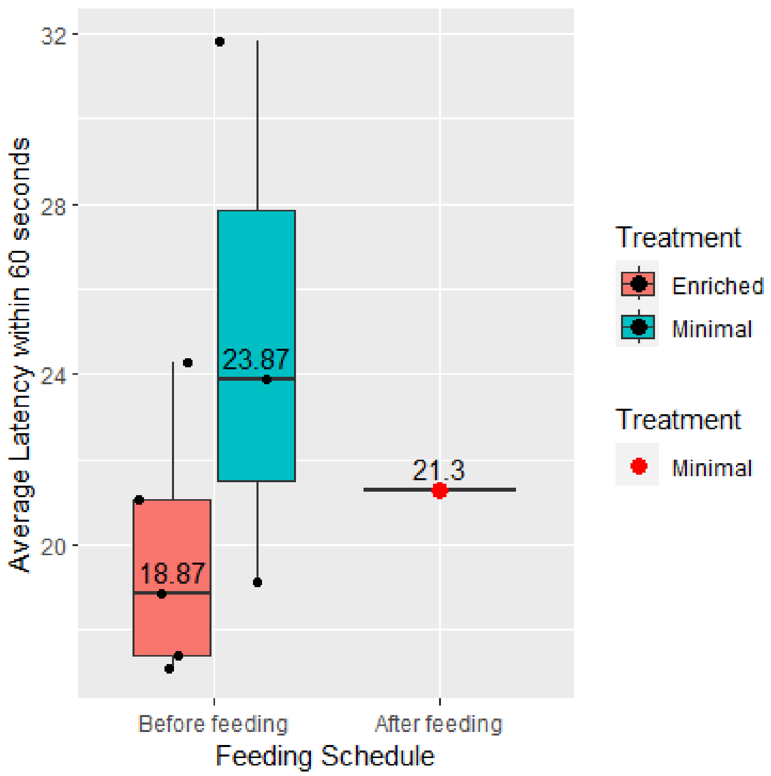


Figure 2 Displays the distribution of the average latency to finger suck for two treatments before feeding and after feeding.

3.3 Oral manipulation

The oral manipulation percentage of each calf from two treatments has been shown in **Figure3**. The box plot is separated into two groups, representing the two treatments -

enriched group and minimal group. Each section corresponds to a different time period: before feeding and after feeding. The individual data points indicate the average oral manipulation percentage of each calf across all observations. In this study I observed that there were distinct patterns in calves' behavior before and after feeding. For the enriched calves, the median oral manipulation percentage was 67 percent before feeding, with the range varying from a minimum of 40 percent to a maximum of 100 percent. After milk feeding, the median percentage decreased to 50 percent, ranging from a minimum of 5 percent to a maximum of 70 percent. In contrast, there may be a difference in minimal calves. Before feeding, the median percentage was 25 percent, with the range varying from a minimum of 0.0 percent to a maximum of 69 percent. After feeding, the median percentage remained at 20 percent, with the range varying from a minimum of 0.0 percent to a maximum of 81 percent. It is noteworthy that the enriched calves continued to show interest in oral manipulation with my fingers even after feeding.

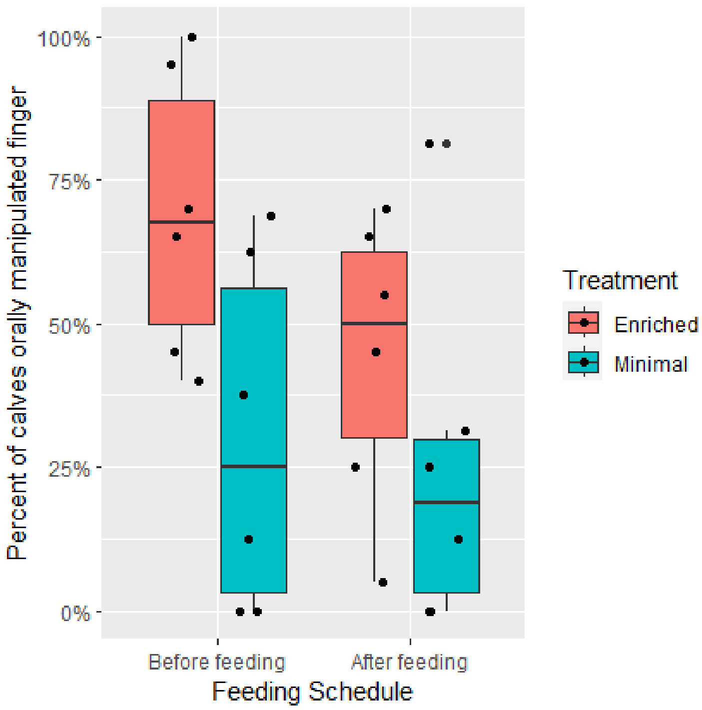


Figure 3 Showing the percentage of oral manipulations of each calf within 60 seconds in both enriched calves and minimal calves.

4 Discussion

The objective of this study was to develop and validate a finger sucking test, making this test an innovative and user-friendly method for on-farm hunger assessment in dairy calves. During the study, I investigated the oral manipulation behavior, finger sucking and latency to suck.

4.1 Finger sucking

I predicted that the finger sucking test is valid and reliable method for assessing hunger in dairy calves. However, upon analyzing the observed results, it becomes evident that the finger sucking test may not be as strongly indicative of hunger as initially anticipated.

Regardless of the treatment, the "After feeding" condition led to reduced finger-sucking behavior in most calves, as evident from the majority of calves (except one from the "Minimal" group) showing a sucking percentage of 0% after feeding. This finding suggests that feeding might have an effect on the calves, leading to a decrease in finger-sucking behavior. In this study, I conducted an assessment of both treatments' post-feeding effects after a 30-minute interval. It is worth noting that previous research by Rushen and de Passillé (1995) tested sucking behavior at 40 minutes after feeding and revealed that pre-meal milk feeding tests did not significantly increase the motivation to do non-nutritive sucking or sucking after milk feeding. Additionally, De Passillé et al. (1992) evaluated sucking behavior at 10, 30, and 60 minutes after feeding using an artificial teat, and their findings indicated a lower level of sucking compared to immediate testing. In this study, I followed a testing interval of 30 minutes post-feeding to assess sucking behavior, a time point that falls between the 10 and 60-minute marks investigated by De Passillé et al. (1992).Therefore, testing at the 10-minute might be no difference with 30-minute, extending the observation period to 60 minutes might increase the sucking motivation in both treatments.

The results indicate that the "Enriched" treatment may have a more pronounced effect on finger-sucking behavior before feeding, as reflected in the wider range and higher median sucking percentage compared to the "Minimal" treatment group. However, after feeding, both treatments seem to result in minimal finger-sucking behavior, with no significant difference between them. However, it is important to note that no statistical analysis was performed to determine the presence of significant differences between the two treatments. Hammell et al. (1988) observed that calves showed a higher preference for sucking dry teat when they were fed ad libitum milk. This study was comparable to results of the current study that the enriched group calves performed more finger sucking than the individually housed ones.

Among the twelve observed calves, 8 calves displayed finger-sucking behavior before feeding, with a majority (5 calves) in the "Enriched" group and fewer (3 calves) in the "Minimal" group. This observation suggests that individual differences might play a role in calf behavior and response to the treatments. Webb et al. (2014) found that variations in food selection performance among individuals have been observed. In a particular study, calves were given the opportunity to choose from different food allowances, revealing a tendency for calves to show a preference for consuming familiar food. However, this inclination exhibited variability within the heifer population, ranging from 0 to 46 percent when encountering new food. So, the individual difference might influence calf eating behavior.

4.2 Latency

I predicted that calves that had access to ad libitum milk allowance have longer latency to suck on my fingers than calves fed restricted milk. Surprisingly, the findings in this study diverged from this prediction. Calves in the enriched group demonstrated a trend toward shorter latency than those in the minimal group. Tapki (2007) found that calves housed in groups exhibit higher levels of activity in play, grooming, licking, and tongue play in comparison to calves housed individually. It could therefore be that enriched calves are willing to perform sucking fingers than minimal calves.

Milk allowance can also influence the latency to suck. One study conducted by Rosenberger et al. (2017), where they offered different amount of milk feeding for calves (6, 8,10 and 12 L/d milk allowance), and found that calves with low milk allowance had more frequent visits to non-nutritive milk feeders. In a similar study conducted by Duve et al. (2012), they made a comparison between the effects of social behavior and milk allowance in calves housed in pairs and individually. The results revealed that calves fed a restricted milk allowance (5 L/d) exhibited higher motivation to consume more milk compared to those fed 9 L/d when housed in pairs. These findings suggest that low milk allowance for calves elicited motivation to suck more milk. However, it is worth noting that in contrast to the minimal calves, the calves with restricted milk allowance appeared to be less active in their behavior. This highlights the potential influence of social factors on feeding motivation and activity levels in the calves.

Previous studies have shown that social environments have impacts to the calves. Gaillard et al. (2014) found that single housed calves have lower cognitive receptivity towards novel stimuli, while group-housed calves demonstrate sensitive for learning new information (Meagher et al., 2015). These findings align with the results observed in minimal calves where they were less interested in finger sucking. It is worth noting, however, that the lack of a specific training component in this study may impact the direct comparability of our results with those of previous studies.

Jensen et al. (1999) investigated the impact of social isolations on calves housed in various conditions and observed that group-housed calves exhibited more evident signs of positive socialization. In addition, calves showed a greater willingness to consume milk when they witnessed other calves engaging in feeding behavior (Nicol, 1995; Miller-Cushon and DeVries, 2016). These studies were comparable to my results where enriched group calves shown shorter latency to suck my fingers.

4.3 Oral manipulation

I predicted that calves would exhibit a higher frequency of oral manipulation of my finger prior to milk feeding compared to after feeding. Indeed, there seemed to be a trend that calves presented more curiosity with fingers before feeding in both experimental groups. Before delving into the specific behaviors observed in our study, it is crucial to distinguish between the actions of sucking and oral manipulation exhibited by calves. Sucking is often associated with a physiological response driven by hunger (Roth et al., 2009). Oral manipulation encompasses with behaviors that often driven by tongue rolling, play and curiosity (Mattiello et al., 2002; Valníčková et al., 2015; Doyle et al., 2022).

Earlier studies have shown that play behavior is higher group housed calves than single housed calves (Valníčková et al., 2015). Jensen et al. (1998) found that calves had less play behavior in limited space. These studies may be the reason why the minimal group calves performed less oral manipulation in both before and after feeding compared to enriched calves. Bøe and Færevik (2003) found that group housed calves performed more social and fearless compared with single housed calves. Indicating that calves in group had more confidence. Jensen et al. (1997) found that calves housed in single pen have more uncomfortable feeling to uncertain environments than group housed calves. These could explain why enriched calves were more curious with oral manipulation.

As shown in Figure 1, it is evident that among the enriched group calves (n=6), four of them exhibited over 65 percent oral manipulation before feeding, while three of them displayed a 50 percent oral manipulation rate after feeding. Conversely, within the minimal group calves (n=6), two calves had 65 percent oral manipulation before feeding, which decreased by 25 percent after feeding. Doyle and Miller-Cushon (2023) found that after milk feeding calves are performed less active to human contact. It could explain that calves from both treatments decreased oral manipulation.

4.4 Methodological limitations

One significant limitation of this study pertains to the individual variability observed in calf behavior. Therefore, replicating or obtaining similar results in subsequent research, particularly concerning calves housed individually in single pens, might present challenges.

Moreover, it is important to acknowledge that certain factors, such as sample size, the presence of background sounds within the barn environment, and differences in social settings among calves, could also impact the generalizability of the findings. The relatively limited sample size in this study may have influenced the extent to which specific behavioral trends were detected. Additionally, variations in ambient sounds within the barn could potentially contribute to variations in calf behavior, affecting the precision of behavioral observations. Lastly, differences in social interactions among calves could introduce complexities.

5 Conclusion

In conclusion, this study offers insights into the finger-sucking behavior of calves in varying housing conditions. The findings suggest that group housing may be associated with heightened finger-sucking motivation, in contrast to individually housed calves, potentially contributing to reduced finger sucking behavior. It is important to note that several management differences existed between the groups, and while a 'restricted' milk allowance appeared to have limited impact on finger-sucking behavior, it is acknowledged that other factors could have influenced these outcomes.

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