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PERSONALITY TRAITS OF DAIRY CALVES AND THEIR RELATIONSHIP WITH FEEDING BEHAVIOR, ACTIVITY, AND PERFORMANCE

Emily A. Michalski
University of Kentucky, emmichalski18@gmail.com
Author ORCID Identifier:
https://orcid.org/0000-0002-2717-2799
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Emily A. Michalski, Student

Dr. Joao H. C. Costa, Major Professor

Dr. David L. Harmon, Director of Graduate Studies

PERSONALITY TRAITS OF DAIRY CALVES AND THEIR RELATIONSHIP WITH FEEDING BEHAVIOR, ACTIVITY, AND PERFORMANCE

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture, Food and Environment
at the University of Kentucky

By
EMILY A. MICHALSKI
Lexington, Kentucky
Director: Dr. Joao H. C. Costa
Assistant Professor of Animal and Food Science
Lexington, Kentucky
2023

https://orcid.org/0000-0002-2717-2799

ABSTRACT OF THESIS

PERSONALITY TRAITS OF DAIRY CALVES AND THEIR RELATIONSHIP WITH FEEDING BEHAVIOR, ACTIVITY, AND PERFORMANCE

Detection of individual differences in personality traits of animals may prove beneficial for producers to help tailor management for individuals and to make selection decisions. Therefore, the objectives of this thesis were to 1) review and evaluate literature on relationships between individual cattle personality traits and feeding behavior, activity, and performance; and 2) evaluate and develop tests suitable for characterizing crossbred dairy-beef calves' personalities and associations with behavioral patterns and performance. The existing literature indicates that growth, intake, activity, and milk production measures from precision technologies have associations with cattle personality traits and behaviors identifiable through standardized tests. This indicates that stable differences among individuals may be identifiable in natural settings. Results from original research indicate that behavioral responses from personality tests (novel person and novel object/startle) of individually housed dairy-beef calves had associations with performance, activity, and feeding behavior. Fearful calves had negative associations with average daily gain (ADG) and dry matter intake (DMI), inactive calves had positive correlations with non-nutritive oral manipulation, and bold calves had no detected associations. Personality trait assessment of dairy-beef calves has potential to predict performance, activity, and feeding behavior on-farm that may help producers make timely decisions fit for their production system.

KEYWORDS: personality, dairy-beef, individual variation

Emily A. Michalski

04/06/2023

DAIRY CALVES PERSONALITY TRAITS RELATIONSHIP WITH FEEDING BEHAVIOR, ACTIVITY, AND PERFORMANCE

By
Emily A. Michalski

Dr. Joao H. C. Costa
Director of Thesis

Dr. David L. Harmon
Director of Graduate Studies

04/06/2023

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CHAPTER 1. REVIEW OF LITERATURE

1.1. Introduction

Animal personality can be defined as a multitude of behavioral responses (i.e. personality traits) that are consistent across time and contexts (Kaiser and Müller, 2021). These personality traits are measured through behavioral responses to different environmental stimuli and during standardized tests. Introduction to a new object, person, or environment would elicit behavioral responses that differ across individuals, and these can be used to identify their personality traits. Fearfulness, boldness, and aggressiveness are often some of the personality trait spectrums that are observed through responses to stressor events (Lecorps et al., 2018). Highly excitable or fearful animals, especially in intensive production systems and with high level of handling, may have detrimental impacts to animal production. Cattle behavior relies on their perception that helps them to communicate with the environment that may prove necessary to survival (Adamczyk et al., 2013). The introduction of novelty, whether a novel object, person, or environment elicits fear response in cattle (e.g. Forkman et al., 2007). Social isolation also elicits behavioral responses from cattle that may indicate fear or nervousness (e.g. Schrader and Müller., 2005). There is evidence in the literature that a relationship between fear or other undesirable traits have a negative relationship with production in cattle. The relationship between fear and productivity in commercially reared cattle may provide farmers with the opportunity to reduce fearful responses that can lead to improve cow productivity and welfare level (Breuer et al., 2000).

Cattle production has had technological progress in genetics, nutrition, reproduction, disease, and management. Cattle are part of production systems that utilize

technology for all aspects of farming, and this technology can be useful in furthering production and behavioral measures that are beneficial to the producer. It is helpful to be able to identify individual behavioral differences to mitigate the negative short term (i.e., stress) and long-term effects (i.e., disease and growth) on the animal. Precision livestock farming (PLF) or precision dairy technology (PDT) is defined as the utilization of real time technology that manages animals as well as collects individual information and/or data on farm (Costa et al., 2021b). Real time technology has the opportunity to increase farm efficiency, or to manage production parameters and the behaviors of the individual (Cantor and Costa., 2022). General on-farm precision technology may include automated calf feeding systems (AFS), automated milking systems (AMS), leg pedometers, and smart collars. Precision technology can measure a myriad of parameters, namely step count, estrus occurrence, daily milk yield, milk conductivity, average daily gain, body measurements, and temperature. Behavioral changes or any deviation from normal behavior will be identified by the precision technology which can alert the producer. Changes in individual behavior could be linked to estrus, calving, or illness. Therefore, identification of behavioral changes using precision technology will help producers to make more timely decisions and improve animal welfare and farm productivity.

Behaviors and measures from precision technology may prove to have a relationship with personality traits based on daily behavioral patterns. Individual behavioral differences have the potential to be measured and identified early in life and should therefore be explored. Precision technology measures themselves can be considered personality traits, but it is not validated presently. Therefore, PT measures will be explored in relation with personality traits from personality or behavioral testing. To

our knowledge, there has been no review in the available literature that identifies precision technologies and how their outputs relate to personality traits. The main aim of this narrative review is to explore the relationship between behavioral responses of the individual from personality tests and the different measures from precision technologies. This review investigates the literature available on growth, feed intake and feeding behavior, activity, and milk production output measures from precision technologies and their relationships to individual personality traits in cattle.

A search of the available research papers published since 2000 was conducted using Google Scholar and Web of Science databases with the following search words: precision dairy technology, precision livestock farming, activity monitors AND dairy, beef, bull, steer, heifer, ruminants, cattle, calf AND personality, personality traits, coping styles, temperament, behavioral patterns, behavioral syndrome AND individual differences, individual variation, behavioral type, accelerometer, sensor. A total of 459 articles resulted from the literature search on Web of Science. These were screened to ensure the articles contained personality or behavioral tests that were compared to variables resulting from precision technologies. The articles from the search on Google Scholar (10,700) were screened utilizing the same criteria for Web of Science. There were 12 articles retained after screening. Additional articles were included following examination of the reference lists of screened articles (8 articles), recently accepted articles from our own research group (1 article), and articles in preparation from our research group (1 article). Thus, the review included a total of 22 articles. The literature search is demonstrated in Figure 1.1 and the literature utilized in the review and all corresponding results is demonstrated in Table 1.1.

1.2. Growth

Measures from the AFS have been related to personality traits found in novel tests. Neave et al. (2019) identified five traits utilizing novelty tests and early life characteristics: “low vitality”, “fearful”, “strong drinker”, “slow learner”, and “exploratory-active”. Calves that scored high for “exploratory-active” trait had a higher pre-weaning, weaning, and total ADG that resulted in higher final BW. This study also found that calves that scored high for the “slow learner” trait (to drink from the feeder) had a tendency for reduced preweaning ADG, and low vitality calves had reduced preweaning ADG. Neave et al. (2018b) reported similar results between automated milk feeding systems and personality traits from standardized personality tests. Furthermore, “exploratory-active” high loaded calves had greater overall average daily gains. This study also found that “interactive” high loaded calves had tendencies for reduced ADG during the full-milk period, and “vocal-inactive” high loaded calves had tendencies for greater ADG during the milk-reduction period. A more recent study also examined the relationship between measures from automated milk feeding systems and personality tests in group housed Holstein calves (Woodrum Setser et al., 2022). Together these studies provide the first evidence of an association between personality traits from standardized personality tests and ADG measures from calves fed using automated milk feeding systems. On the other hand, one general on-farm precision technology that can be utilized to measure growth in cattle is the scale incorporated with AFS. Further research should investigate the ability of such variables in early life to predict growth and potentially tailor individualized management for the animals.

1.3. Feed Intake and Feeding Behavior

Another variable that can be measured utilizing precision technologies on farm is milk and/or solid feed intake. In addition to growth, AFS can also measure intake for individual calves. Neave et al. (2018b) reported that "exploratory-active" trait high loaded calves consumed more grain in pre-weaning, weaning, and post-weaning periods. In addition, calves that were slow to learn to use the automated feeder had reduced preweaning and overall dry matter intake, driven primarily by reduced milk intake, while the fearfulness trait had no association with feed intake (Neave et al., 2019). Whalin et al. (2022) also explored the relationship between intake from automated milk feeders and personality traits from personality tests. Calves that were loaded higher for the "playful/exploratory" trait consumed more milk per day in preweaning and had higher feed intake per day. In contrast, the "vocal/inactive" trait was negatively associated with preweaning milk intakes and lower concentrate intakes over the experimental period. Lastly, "interactive" trait high loaded calves had lower preweaning and weaning concentrate intakes. Another study identified "fearful", "bold", and "active" traits from standardized personality tests and related it to intake measures from the automated milk feeding system (Woodrum Setser et al., *in preparation*). Together these studies suggest that exploratory and/or playful calves have a positive association with milk or feed intake, activeness in calves have negative associations with milk intake.

In adult dairy cattle milked in an automated milking system (AMS) and fed from automated feed bins, cows that were high loading on the "alert-curious" trait consumed more of a partial mixed ration; while cows that were more fearful of a novel human were less likely to consume their concentrate allowance in the AMS, resulting in less total DMI and more variability in intake (Schwanke et al., 2022). Several studies in beef cattle have

also reported reduced feed intake at the feedlot in individuals with greater agitation score and flight speed in a chute test (Cafe et al., 2011a; Elzo et al., 2009), and high reactivity when isolated in a pen with a handler (Black et al., 2013). The consumption of feed necessarily involves feeding behavior patterns that are also variable among individuals. Some of the above-mentioned studies reported some relationships between personality traits and measures of feeding behavior patterns, such as visits to the milk feeder (Neave et al., 2018b, 2019; Whalin et al., 2022) or AMS visits resulting in concentrate delivery (Schwanke et al., 2022). Additionally, grazing time in pastured dairy cattle (measured using an ear-based accelerometer) was greater in more calm-investigative individuals (Neave et al., 2022). A focus on these feeding behavior patterns can be insightful. A recent study used the behavioral patterns of AFS use in dairy calves to characterize personality, where consistent individual differences in meal frequency and drinking speed formed a personality trait that predicted weight gain (Carslake et al., 2022a). Future research should be conducted to further explore how intake and feeding behaviors of cattle can be predicted utilizing measures from precision technologies and tests that identify the personality of the animal.

1.4. Activity

Activity of individuals can be measured utilizing precision technologies such as tri-axial accelerometers and can be related to personality traits identified from personality tests. In a study of pastured dairy cattle, cows that were more fearful of humans had reduced lying time (measured using leg-based accelerometers) (Neave et al., 2022). Another study identified three personality traits from standardized personality tests (“neophobia”, “vocalization”, and “boldness”) and related it to activity measures from tri-axial

accelerometers in dairy cows (MacKay et al., 2014). Neophobic cows exhibited more lying bouts and greater variation in average duration of lying bouts. Bold cows were less variable in their average lying bout duration, and cows more tolerant of human approach had fewer lying bouts per day and shorter average standing bout duration. Research in beef cattle has related differences in flight speed and chute scores to activity measures from tri-axial accelerometers (MacKay et al., 2013). The high flight speed response of individuals was positively associated with activity in the home pen and variability in step count. This study also found that steers that had high displacement index had less daily lying time and long average standing bout durations. Bruno et al. (2018) utilized an ear tag accelerometer and identified behavioral characteristics of beef steers from chute exit velocity and an objective chute score (measuring variability in weight recordings). Steers that exhibited low objective chute score tended to have higher daily activity counts than high objective chute score steers and steers that displayed fast exit velocities had higher activity counts than steers that had slower exit velocities.

In individually housed crossbred calves, standardized personality tests identified fearful, inactive, and bold traits and revealed a relationship with activity from tri-axial accelerometers (Michalski et al., 2023). The score for the trait inactive from standardized personality tests had negative associations with mean motion index and mean steps from leg accelerometers. No other personality traits had associations with activity. Lastly, group housed Holstein calves were classified as “fearful”, "bold, or “active” from standardized personality tests and compared to tri-axial accelerometer activity (Woodrum Setser et al., *in preparation*). Fearful calves had significant positive associations with steps and activity index. Bold calves had significant positive associations with steps and active calves had no

associations with activity. Together these studies demonstrate measures of personality from standardized tests are associated with activity in the home environment. Recent work has explored solely using precision technologies to characterize personality, without the use of standardized personality tests; location sensors determined consistent individual variation in movement and space use, demonstrating active and exploratory personality traits (Occhiuto et al., 2022). Thus, there is opportunity to identify characteristic personalities using precision technologies from day-to-day recordings of activity, and further research should explore how differences in activity relate to individual personalities.

1.5. Milk Production

Milk production of mature cattle can be measured using automated milking systems, or associated software. The information from this precision technology can be used along with personality and behavioral tests to further explore whether producers can make timely decisions based on the results. Some of the first studies exploring this relationship found that milk yield was lower in cows that were more fearful or reactive toward humans in a standardized test (Hemsworth et al., 2000;Breuer et al., 2000), but more recent studies have found mixed results regarding the human-animal relationship and milk yield. Greater avoidance distance (i.e. cows more fearful of humans) was positively correlated with milk flow rates during weeks 1 and 6 of lactation and milk yields during week 6 of lactation (Sutherland and Dowling., 2014), while Sutherland et al. (2012) and Neave et al. (2022) did not observe any relationships between behavioral responses in a series of novel human tests and milk yield. Behavioral responses to a novel object test have also produced contrasting findings, with one study demonstrating increased milk yield in pastured dairy cows that were more “curious/investigative” (Neave et al., 2022) and two

others showing no effect in indoor housed dairy cows (Hedlund and Løvlie., 2015; Marçal-Pedroza et al., 2020). However one of these studies demonstrated a relationship between milk yield and a social isolation test, where more fearful (vocal) cows had lower milk yield (Hedlund and Løvlie., 2015). Recent work has used data from milking robots that are growing in popularity among producers. Schwanke et al. (2022) utilized personality tests to identify active, social, and alert-curious cattle within the novel environment and object tests, and active-vocal and fearful cattle in the novel person test. Cows who were more active in the novel arena and object tests had lower milk production at enrollment. Overall, these studies indicate the value of characterizing personality traits of dairy cattle to understand variability in milk production; future research should explore whether personality traits throughout life can predict milk production in the mature cow using precision technologies.

1.6. Conclusion

Emerging research indicates that personality traits (consistent individual differences in behavior) of cattle have relationships with production, activity, and feeding behavior. Cattle behavior can be measured utilizing standardized behavioral tests, referred to as personality tests. Further, precision technologies exist that can compute activity, production, and feeding behavior measures. This limited literature review reveals there is a clear relationship between the measures from these precision technologies and personality of individual animals. This relationship can be utilized to identify individuals that require greater attention from the producer, and those that are performing well, allowing for more timely decisions (such as animal selection) for the future of the farm. Future research should explore how precision technologies can characterize and identify

animal personality traits that predict individual variability in performance on commercial operations.

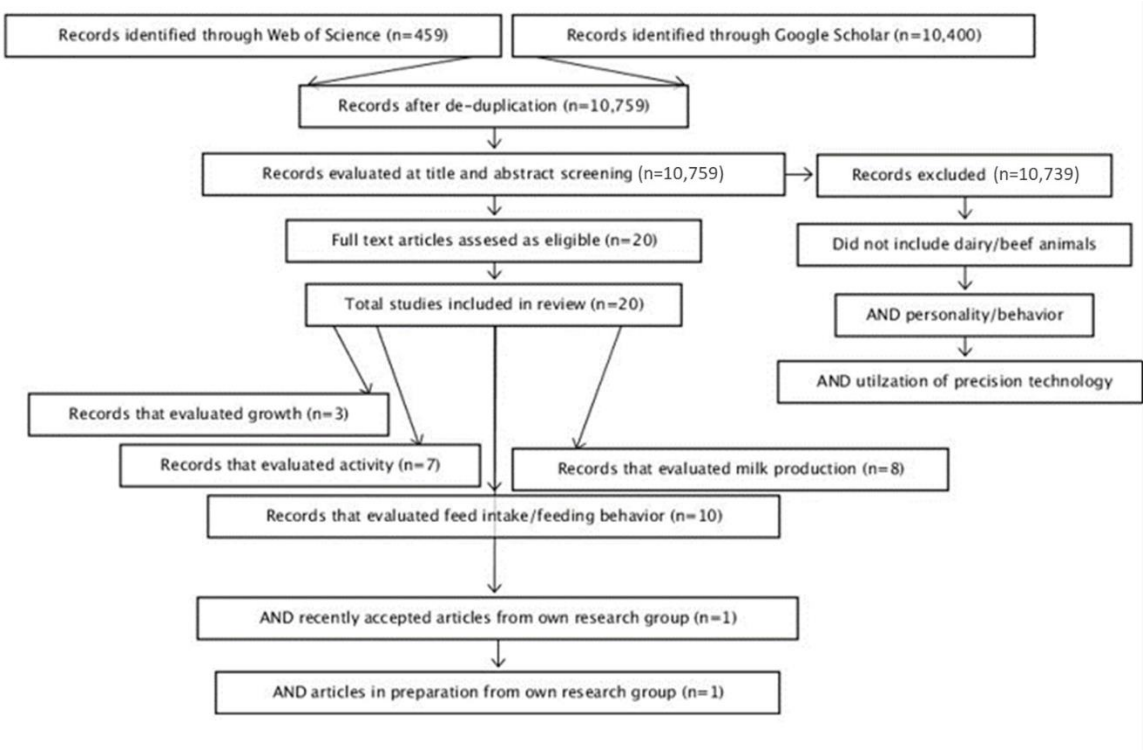
Table 1.1 Summary of literature utilized in the review and corresponding results.

Variable	Citation	Result
Growth	Neave et al., 2019	Exploratory-active ↑ preweaning, weaning, total ADG; slow learners ↓ preweaning ADG; low vitality ↓ preweaning ADG
	Neave et al., 2018b	Exploratory-active ↑ ADG; interactive ↓ ADG during full milk period; vocal-inactive ↑ ADG during milk reduction period
	Woodrum Setser et al., 2022	Recent study also examined AMFS and personality
Feed Intake and Feeding Behavior	Neave et al., 2018b	Exploratory-active ↑ grain intake preweaning, weaning, and post-weaning periods
	Neave et al., 2019	Slow learners ↓ preweaning/overall ADG; fearful no association; relationship between traits and visits to milk feeder
	Whalin et al., 2022	Playful-exploratory ↑ feed intake/d and milk/d preweaning; vocal-inactive ↓ preweaning milk intake and feed intake; interactive ↓ preweaning/ weaning feed intake; relationship between traits and milk feeder visits
	Woodrum Setser et al., *in preparation*	Fearful, bold, active traits and related to intake measures
	Schwanke et al., 2022	Alert-curious ↑ intake partial ration; fearful ↓ intake and ↓ total DMI and ↑ intake variability; relationship between traits

		and AMS visits resulting in feed delivery
	Cafe et al., 2011a	↑ Agitation score/flight speed in chute ↓ feed intake in feedlot
	Elzo et al., 2009	↑ Agitation score/flight speed in chute ↓ feed intake in feedlot
	Black et al., 2013	High reactivity in pen with handler ↓ feed intake in feedlot
	Neave et al., 2022	Calm-investigative ↑ grazing time in pasture
	Carslake et al., 2022a	Consistent individual differences in meal frequency/drinking speed formed personality trait predicted weight gain
Activity	Neave et al., 2022	Fearful of humans ↓ lying time
	Mackay et al., 2014	Neophobic ↑ lying bouts and ↑ avg duration lying bouts; Bold ↓ variable avg lying bout duration; tolerant of humans ↓ lying bouts/d and ↓ avg standing bout duration
	Mackay et al., 2013	↑ Flight speed ↑ activity in home pen and ↑ variability in step count; ↑ displacement index ↓ daily lying time and long avg standing bout durations
	Bruno et al., 2018	↓ Objective chute score ↑ daily activity counts; fast exit velocities ↑ activity counts
	Michalski et al., 2023	Inactive ↓ associations with mean motion index and mean steps
	Woodrum Setser et al., *in preparation*	

	Occhiuto et al., 2022	Fearful ↑ associations with steps and activity count; bold ↑ associations with steps Location sensors determined consistent variation in movement/space use = active and exploratory traits
Milk Production	Hemsworth et al., 2000	Fearful/reactive toward humans ↓ milk yield
	Breuer et al., 2000	Fearful/reactive toward humans ↓ milk yield
	Sutherland and Dowling, 2014	↑ Avoidance distance ↑ correlated with milk flow rate in weeks 1 and 6 of lactation and milk yields during week 6 lactation
	Sutherland et al., 2012	No relationship between human responses and milk yield
	Neave et al., 2022	No relationship between human responses and milk yield; curious/investigative of pastured ↑ milk yield
	Hedlund and Løvlie, 2015	No effect in milk yield in curious indoor housed; fearful/vocal ↓ milk yield
	Marçal-Pedroza et al., 2020	No effect in milk yield in curious indoor housed cows
	Schwanke et al., 2022	Active ↓ milk production at enrollment

Figure 1.1. Results of the literature search strategy and article selection. Articles were screened to ensure the articles contained personality or behavioral tests that were compared to variables resulting from precision technologies. A total of 10,809 articles were screened at title and abstract, with 10,787 not meeting eligibility criteria. A total of 22 full text articles were retained for the literature review.



CHAPTER 2. PERSONALITY OF INDIVIDUALLY HOUSED DAIRY-BEEF CROSSBRED CALVES IS RELATED TO PERFORMANCE AND BEHAVIOR

2.1. Introduction

Animal personality can be defined as individual differences in behavior that are consistent across contexts and time, and specific aspects of this behavioral repertoire are referred to as personality traits (Kaiser and Müller., 2021). These individual differences in behaviors may be assessed and interpreted from standardized tests, often by exposing animals to stressful situations (Finkemeier et al., 2018). In cattle, personality traits show long term consistency from early age to adulthood (Neave et al., 2020), and some traits are moderately heritable, such as handling traits of beef cattle and milking temperament of dairy cattle (Haskell et al., 2014). However, undesirable personality traits, such as fearfulness, could be inherited by future offspring in both beef and dairy cattle (Haskell et al., 2014; Dochtermann et al., 2015). For commercial operations various studies linked personality to individual performance, behavior, productivity, and welfare level (Haskell et al., 2014). Therefore, the measurement of personality traits across livestock production systems is vital to adapt management practices for improved production and animal welfare.

The environment that individuals are exposed to contributes to their expression of personality traits and behaviors (Dingemanse et al., 2010). Calf management varies across farms and utilizes either individual, pair, or group housing. Housing directly impacts early social environments which have been associated with calf behavioral responses to novel stimuli. For instance, calves that were isolated were associated with increased scores that reflected fear (Jensen et al., 1997). This effect of the environment

on expression of personality traits in animal have been seen in many species; rats that were individually housed (and thus socially isolated) showed abnormal responses to novel stimuli, including greater locomotor activity and more bouts of exploration (Sahakian et al., 1977). The expression of abnormal behaviors, such as excitable behaviors and fear of humans and/or confinement, can be detrimental to production in cattle and have been linked to decreased growth rates, lower meat quality, and decreased milk production (Haskell et al., 2014). In Brahman cattle, poor temperament reduced DMI and ADG and had darker meat with smaller carcasses with less fat cover (Cafe et al., 2011). Hemsworth et al. (2002) reported that the avoidance distance in the human approach test is negatively associated with milk yield in cattle on farms. There is also evidence to suggest that abnormal responses such as stress and no display of sickness have a negative impact on immune function in cattle (Hulbert et al., 2011). Animals with personalities that are linked to chronic stress are at increased risk for long-term negative consequences (Koolhaas and Van Reenen, 2016).

The way animals interact with their environment, including the feeding environment, is also influenced by their personality traits. Calves that were more exploratory/active during novelty tests consumed larger quantities of solid feed and had higher ADG (Neave et al., 2018a). Thus, differences in personality traits may explain why some animals either fail or succeed in learning and adapting to their feeding environment (Neave et al., 2018b). Another aspect that may impact feeding behavior are the introduction of novel diets to ruminants that have been shown to decrease feed intake (Launchbaugh et al., 1997). This rejection of novel feeds, or food neophobia, has been

measured in dairy cattle and was a contributing factor affecting feed intake (Cooke et al., 2006; Costa et al., 2020).

One method to measure personality traits is through the utilization of a standardized test that introduces a novel stimulus in the environment and objectively measures individual behavioral response. This novel stimulus may be the environment, an object, or a person to measure personality traits such as fearfulness, exploration, and boldness in cattle (Forkman et al., 2007). The reactivity and responsiveness of calves during standardized tests can be attributed to a underlying personality trait such as fearfulness (Van Reenen et al., 2004). These tests may measure multiple traits which may make isolating a single trait such as fearfulness difficult. The introduction of an alternative standardized test to isolate the fearfulness trait, the startle test, may help differentiate between the expression of fearful and other personality traits such as exploration (Lauber et al., 2006). The use of a myriad of standardized tests allows for a more holistic view of personality traits in individuals. It is important to note that most of the personality research in calves are in animals that are group housed, yet individual housing is predominantly used in the dairy industry. The associations of personality traits with performance and behavioral indicators of calves in individual housing is therefore worthy of investigation.

In addition to a focus on group housed calves, available personality research has mostly focused on adult cattle, and previous work in pre-weaned animals has been performed in dairy calves. This lack of investigation on beef or dairy-beef crossbred calves in conjunction with the surge of interest in beef-on-dairy production creates a need for this investigation. Crossbreeding provides the opportunity to improve health and

production efficiency of plants and animals through hybrid vigor (VanRaden and Sanders, 2003). There are clear benefits in reproduction, genetics, production, and increased value of surplus calves in the dairy industry (Berry, 2021). For example, dairy-beef crossbreeds improved calving ease in the dam and overall genetics of the herd (Eriksson et al., 2020) as well as higher yield and quality of the carcass (Bertrand et al., 1983). With the increased attraction to dairy-beef calves' production and potential monetary benefits to the producers, it is important to understand behavior and personality traits of crossbred calves, as these may have similar or different associations with performance and behavior than dairy or beef animals.

The main objective of this study was to evaluate a series of tests suitable for characterizing personality traits in individually housed dairy-beef crossbred calves. We aimed to 1) characterize behavioral responses of individually housed dairy-beef crossbred calves utilizing the novel person, novel object, and startle tests, and 2) evaluate the association between personality traits, calf performance and home pen behaviors, including feeding behavior and activity. We hypothesized that standardized behavioral tests adapted for use in the home pen of individually housed crossbred calves can reflect personality traits and will be associated with calf performance and home pen behavior.

2.2. Materials and Methods

Dairy-beef (Holstein X Angus) crossbreed bull calves (n = 31: 2 blocks) were sourced from a single commercial dairy producer in Indiana, USA and transported to the University of Kentucky Large Animal Unit in Lexington, Kentucky. Before arrival to the facility, calves were housed in individual hutches on the commercial dairy. Calves were 8.5 ± 2.1 days of age at arrival. Calves were simultaneously enrolled in a 76-day study and were managed under the approval of the University of Kentucky's Institutional

Animal Care and Use Committee (IACUC #: 2019-3156). Block 1 calves (n=16) were 8.0 ± 2.0 d old (49.0 ± 5.6 kg) on arrival (Aug 10, 2020), and Block 2 calves (n= 15) were 9.0 ± 2.2 d of age (49.4 ± 9.0 kg) on arrival (January 26, 2021). Two calves were excluded from the study due to illness, so only 29 were utilized.

2.2.1. Calf Management

Calves were housed individually indoors in an environmentally controlled room (20.9 ± 0.5 °C and 79.4 ± 5.0% relative humidity). Individual pens were 2.5 m in length and 2.6 m in width, totaling 6.5 m^2. All pens were fitted with rubber mats on the floor. Calves were socially isolated and could not see others between pens. Calves had *ad libitum* access to water and pelletized calf starter with 18% CP and 2.5% fat (Bagdad Feeds, Bagdad, Kentucky) in buckets. Calves were nipple-bottle fed 7 L/d of milk replacer at approximately 830 and 1730h (Cow's Match Warm Front, Land O Lakes, Minnesota; 1 L, 150 g/L) that was divided into two equal meals until day 41. On day 42, milk replacer was reduced to 3.5 L/d between two equal meals. Calves were weaned on day 56 and continued to be managed post-weaning until completion of the experiment on day 76. Health checks were performed daily before morning feeding to assess for clinical signs of Bovine Respiratory Disease (BRD) and diarrhea following (Cantor et al., 2021). Four calves were diagnosed with a minor BRD case and received enrofloxacin subcutaneously (Baytril, Bayer, Leverkusen, Germany; 1 ml/15 kg) following the herd veterinarian protocol. Two calves were diagnosed with severe BRD and were treated with subcutaneous tulathromycin (Draxxin, Zoetis, Florham Park, NJ; 1.2 ml/45 kg) and intravenous flunixin meglumine (Banamine, Merck Animal Health, Madison, NJ; 0.5 ml/15 kg). Once weekly, calves were weighed to track growth and lungs were evaluated via ultrasonography to assess internal signs of pneumonia following (Ollivett and

Buczinski, 2016). Calves indicating signs of illness were given treatment according to the protocol developed with the veterinarian from the Department of Veterinary Sciences at the University of Kentucky.

2.2.2. Home Pen Behavior and Performance Measures

Each calf was fitted with a pedometer (IceQube, IceRobotics Inc. Edinburgh, Scotland), validated for use in herd management and research (Trénel et al., 2009). This pedometer was a 3-axis accelerometer that uses algorithms to determine relative position to the ground and speed and direction of movement (Robert et al., 2009, Costa et al., 2021). Calf activity behaviors were measured daily for the duration of the experiment including standing time, motion index, step count, lying time, and lying bouts extracted from the pedometer. These activity measures were summarized from daily values to obtain an average per calf across the experimental period.

Individual body weight was measured and recorded weekly using a scale, then summarized to obtain an average daily gain (ADG) per calf over the experimental period. Calf starter (grain) dry matter intake (DMI) was recorded daily by measuring grain orts, or leftovers, and calculating disappearances during the whole experimental period; daily intakes were summarized to obtain an average daily grain intake per calf over the experimental period.

Feeding behaviors were recorded on days 13, 32 (prior to step down), 53 (prior to weaning), and 67 (one week post weaning) using a camera (Moultrie M40i, Moultrie Feeders Birmingham, AL) that recorded images of the water and grain buckets in 1-minute intervals. The use of time-lapse cameras has been validated for this purpose (Miller-Cushon and DeVries, 2011). The images obtained from the camera (n=164,457) were scored by a single observer for daily duration of feeding behaviors (defined as

muzzle inside of the rim of the feed or water bucket; Miller-Cushon and DeVries, 2011), and daily duration of non-nutritive oral behaviors (defined as licking or biting buckets or walls, without the purpose of feed or water ingestion; Montoro et al., 2013). These two behaviors were summarized to obtain a daily average per calf across the 4 observation days. Other recorded behaviors were not accounted for, including when calves were out of view of the camera and behavior could not be determined. These behaviors were not of interest and thus were not included in the analysis.

2.2.3. Standardized Personality Tests

Calves underwent three standardized personality tests at d 75 of the experimental period within their home pen. Tests were performed in the following order for all calves: novel person then a combined novel object/startle test, adapted from Woodrum Setser et al. (2022). All behaviors were continuously monitored with a camera (HERO9 Black, GoPro Technology, San Mateo, California) centrally mounted above each individual pen. During each test, a single observer sat out of sight outside the pen and recorded any audible vocalizations. All tests for an individual calf were performed within a single day, with no time between tests.

2.2.3.1.Novel Person tests

Briefly, calves were temporarily removed from their home pen to allow for placement of a novel person inside their home pen. The novel person, who had never interacted with the calves before, was dressed in a neon yellow construction jacket with their head covered and pants in the back corner of the calf's pen. The novel person had their hands inside their pockets, had the jacket's hood drawn up, and wore a medical face mask covering nose and mouth (i.e., eyes were visible). The person faced the front of the pen and was instructed to not interact with the calf. After a 10-minute test period, the calf

was removed from their pen and held in the alley outside its home pen to allow the person to exit and to set up for the next test. Video observations and manual vocal observations were recorded for the duration of the novel person tests. The behaviors measured were the latency to approach novel person, time spent touching novel person, exploring environment, inactive, walking, resting, attentive to person, grooming, and playing. Additionally, the frequency of bucking, withdrawals, and urination/defecation were recorded (see ethogram in Table 2.1).

2.2.3.2.Novel Object/Startle tests

Immediately following the novel person test, the calf experienced a combined novel object and startle test. While the calf was held in the alley outside its home pen after the novel person test, a remote-controlled car (10-inch 20V Big Wheel Remote Control Monster Truck RC, Kid Galaxy, Manchester, New Hampshire) was placed up against the middle of the right wall panel inside the pen. The car remained motionless until the calf approached the car (defined as touching the car with its muzzle), or until 5 minutes lapsed without the calf approaching. Once approached, or after the 5-minute interval, the car sped across the pen toward the left wall panel, triggered using a remote control held by the researcher outside the pen that was out-of-sight of the calf. Once reaching the opposite wall, the car stopped movement and remained in this position for the remainder of the test. From the moment the car reached the opposite wall, calves were observed for an additional 5 minutes to determine whether the calf decided to re-approach the car after being startled.

Video observations and manual vocal observations were recorded for the duration of the novel object/startle test. The behaviors measured from video were latency to initially approach the object before the startle, latency to re-approach the object after the

startle, and time spent touching the object, exploring environment, inactive, resting, walking, attentive to object, grooming, and playing. Additionally, the frequency of bucking, withdrawals, and urination/defecation were recorded (see ethogram in Table 2.1). To ensure that test length was the same for all calves regardless of whether the calf approached the object initially, only latency to initially approach was recorded before the startle; all other behaviors were recorded after the startle, during the last 5 minutes of the test period. All behaviors that were recorded after the startle include latency to re-approach the object after the startle, and time spent touching the object, exploring environment, inactive, resting, walking, attentive to object, grooming, and playing. If a calf did not initially approach the object within 5 minutes, latency to initially approach was recorded as the maximum 5 minutes. If a calf did not re-approach the object after the startle (from the moment the car moved), latency to re-approach was recorded as the maximum 5 minutes. Duration and frequencies of all behaviors (except latency variables) were summed across the novel person test and novel object/startle test per calf. A single observer recorded all behaviors in the tests from video using a behavioral coding software (The Observer XT 14, Noldus Information Technology, Wageningen, The Netherlands) according to the ethogram (Table 2.1).

2.3. Statistical Analysis

All statistical analyses were performed with SAS (version 9.4; SAS Inst. Inc., Cary, NC) with calf as the experimental unit. All variables were inspected for normality utilizing the UNIVARIATE procedure and probability distribution plots in SAS. Grooming and inactive variables from the personality tests were not normally distributed and were transformed using $\log_{10}$. The variables withdrawal, resting, urinating, and

defecating were removed from analysis since they rarely occurred and were not able to achieve a normal distribution with transformation.

A correlational multivariate analysis was used to identify common sets of behaviors across the different tests, followed by a subjective interpretation of the correlated sets of behaviors according to Costa et al. (2020). Labels were assigned to these sets of behaviors, guided by literature, which were interpreted as personality traits. A principal component analysis (PCA) with varimax rotation (PROC FACTOR) was used to reduce correlated measures from the novel person and novel object/startle tests, following analysis and reporting guidelines outlined by (Budaev, 2010). The PCA included 8 input variables: latency to initially approach novel object, latency to re-approach novel object after the startle, latency to approach novel person, time spent attentive to novel person or object, time spent grooming, time spent inactive, time spent touching novel person or object, and time spent locomotory and object playing. The variables walking and time spent exploring environment were removed from the PCA analysis as they lowered the Kaiser–Meyer–Olkin measure of sampling adequacy (requirement of 0.50 to conduct PCA). The correlation matrix was computed, and principal components were retained if eigenvalues were > 1. Three principal components (factors) were retained that explained 76.1% of the variance in behavioral responses in the novel person and novel object/startle tests. Factor scores for each calf were extracted using the regression method; each calf received a score on a continuous scale for each factor (interpreted as a personality trait). These scores were then utilized to explore associations of factor scores (personality traits) with calf performance and home pen behaviors.

To explore associations between the factors scores (personality traits) and performance during rearing and home pen behaviors, linear regressions were performed (PROC MIXED). The factor scores yielded from the personality tests were the explanatory variables, and response variables were calf performance (ADG, daily grain intake), home pen feeding behaviors (eating time, drinking time, and non-nutritive oral behavior), and home pen activity (motion index, standing time, lying time, mean steps). Enrollment age, body weight at arrival, and block were included as fixed effects. Treatment with antibiotics (yes or no; n = 6 calves were treated) was also included as a fixed effect as a control for incidence of BRD throughout the study, but this variable was not significant. Fixed effects were removed from the model using stepwise backwards elimination if $P > 0.30$ starting with the least contributing effect. Findings were deemed significant if $P \leq 0.05$ and a tendency when $P \leq 0.10$.

2.4. Results

2.4.1. Personality Traits from Principal Component Analysis

The behavioral responses of calves during the novel person and novel object/startle test are reported in Table 2.4, and the variable loadings on each factor are reported in Table 2.5. Factor 1 explained 40.5% of the variance and yielded high positive loadings for latency to initially approach the novel object, latency to re-approach the novel object after startle, and time spent attentive to novel person or object. Factor 1 also had negative loading times for time spent touching person/object and time spent playing with person/object. Calves with a higher score on this factor were labeled “fearful”. Factor 2 explained 18.8% of the variance and yielded high positive loadings for time spent grooming and time spent inactive. Factor 2 also had negative loading times for time spent playing with person/object and time spent touching person or object. Calves that

scored high on this factor were labeled as “inactive”. Factor 3 explained 16.9% of the variance and yielded high positive loadings for time spent touching person or object and high negative loadings for time spent playing. Calves with a higher score on this factor were labeled as “bold”.

2.4.2. Associations between Personality, Performance and Home Pen Behaviors

Calves spent (mean ± SD) 38.1 ± 10.6 min/d (range: 25.3 – 65.5 s/d) eating, 5.4 ± 4.0 min/d (range: 0 – 13.5 min/d) drinking, and 25.4 ± 11.4 min/d (range: 4.5 – 40.5 s/d) engaged in non-nutritive oral behavior while in their home pen. The performance and feeding behavior data for each calf is in Table 2.2 and the activity measures for each calf is in Table 2.3. The relationships between calf performance, home pen behaviors, and the factor scores (personality traits) are outlined in Table 2.6. Factor 1 (“fearful”) had a negative association with total average daily gain and average grain intake (Figures 2.1, 2.2). Factor 1 had no associations with any home pen behaviors. Factor 2 (“inactive”) had a positive association with average time spent licking (non-nutritive oral behavior; Figure 2.3). Factor 2 also tended to have negative associations with mean eating time, mean motion index, and mean steps. Factor 3 (“bold”) had no associations with any of the performance or home pen behavior measures.

2.5. Discussion

This is the first study to investigate personality traits in dairy-beef crossbred calves reared in social isolation, and to evaluate relationships between personality, performance, and home pen behaviors in these calves. Calves were reared in individual pens, with solid walls on each side of the pen to prevent physical and visual contact with other calves. The series of tests performed in this study were able to suitably be associated with performance and home pen behaviors. Calves that were more “fearful”

consumed less grain and had reduced ADG, while calves that were more "inactive" spent more time expressing non-nutritive oral behaviors (i.e., licking buckets or walls) and tended to spend less time eating and moving. These results have important implications for understanding individual variation in behaviors of calves during the rearing period, which could potentially signify animals with poorer performance and provide an on-farm selection strategy for rearing dairy-beef crossbred calves.

2.5.1. Personality Traits of Crossbred Calves

Similar to previous study approaches in farm animals, personality traits were identified using a principal component analysis on the behaviors expressed during three standardized personality tests (Woodrum Setser et al., 2022; Whalin et al., 2022; Costa et al., 2020; Neave et al., 2018a). The pattern of factor loadings revealed how the novel person, novel object and startle tests can measure common or different aspects of calf personality. For instance, measures from the startle test (latency to initially approach and re-approach the novel object) loaded together with a measure from the novel person test (time spent attentive) on factor 1 ("Fearful"). The other factors, "Inactive" and "Bold", were comprised of a combination of measures from all three tests (inactive, grooming, play, and touching the novel object and person). Notably, latency to approach the novel person did not load highly on any factor, indicating that a single measure from a single test was not sufficient to reflect a personality trait. The pattern of factor loadings from crossbred calves in this study supports previous work in dairy calves (Van Reenen et al., 2004; Neave et al., 2018a, 2019; Costa et al., 2020; Woodrum Setser et al., 2022) in the use of multiple standardized tests to identify personality traits in young cattle. It also supports a previous study (Woodrum Setser et al., 2022) in the use of a startle test to

reveal individual variability in “fearfulness” in calves. However, research has yet to describe multiple personality traits in young beef calves.

A key difference from other calf studies of personality is the application of behavior tests in the home pen rather than in a separate test arena. We also housed calves individually rather than in group housing, which is typical of current commercial practice for dairy and dairy-beef crossbreds (USDA., 2016). The factors from the PCA in this study were similar to other studies in group housed calves, but some key differences were also observed. The factor “fearful” in our study had high positive loadings for latency to approach and touch the object before and after the startle, and the time spent attentive looking toward the person and object. A previous study by Woodrum Setser et al. (2022) in group-housed dairy calves used the same three personality tests as the current study, except these tests were performed in a test arena separate from the home pen; these authors reported a similar pattern of factor loadings to ours. Other studies that performed novel object and novel human tests in a test arena in group-housed calves (Neave et al., 2019; Lecorps et al., 2018) also showed a collective “Fearful” personality trait using similar relationships among behaviors from these tests. Together these studies suggest that “fearfulness” of calves was measurable across test situations (in home pen or test arena), across housing conditions (individually or group-housed calves), and in both dairy and crossbred calves.

In this study, the factor “inactive” had high positive loadings for the time spent inactive and grooming during the standardized personality tests. This behavior “inactive”, or its inverse “active”, appears to consistently form a separate factor from other behaviors recorded across multiple personality tests, supporting that (in)activity forms an

underlying personality trait in calves (Van Reenen et al., 2004, Van Reenen et al., 2005; Neave et al., 2018b). Notably, these previous studies in group housed calves also had a measure of exploring the environment that was well correlated with pen activity. In this study, time spent exploring the environment was removed from analysis as it lowered the MSA score of the overall PCA, suggesting it was not explaining sufficient variation in the behavior of our individually housed calves. Our calves were tested in their home environment, which was not novel and was limited in size due to individual housing, so these conditions may not promote exploratory behaviors. This result may indicate that exploratory behavior may not be an informative measure of personality for individually housed calves tested in their home pen. There may be a breed effect causing this difference; more research on individually housed calves of various breeds may reveal the usefulness of this measure of exploration in describing personality of calves.

Finally, the "bold" factor in this study had high loadings of time spent touching the person or object which is consistent with Costa et al. (2020). However, our "bold" factor did not include the latency to approach the person, which was observed in group housed dairy calves exposed to the same tests (Woodrum Setser et al., 2022). The latency to approach the novel person is often interpreted as a measure of boldness or fearfulness in calves (Forkman et al., 2007), yet this measure could not explain sufficient variation in behavior in our calves. The average latency to approach the novel person was just 7 seconds, which could indicate that testing in the home environment (rather than a novel arena, as in most other studies; Forkman et al., 2007), or being individually housed, made calves more comfortable to approach a novel human. However, the novel person test is still useful to characterize personality, given other measures from the test contributed to

the “Fearful” and “Bold” traits. Similar to Woodrum Setser et al. (2022), this study included a startle test that was expected to help distinguish measures related to fearfulness (i.e. a negative response to a real or perceived threat; Boissy., 1995) from measures related to boldness (i.e. the propensity to take risks, particularly when faced with novel situations; Toms et al., 2010). The measures specific to the startle (latency to re-approach) and attentive behavior (reflecting vigilance following a threat; Welp et al., 2004) loaded together, providing support for the use of novelty and startle tests to characterize separate boldness and fearfulness traits in calves.

2.5.2. Personality and Growth Performance

Growth in both beef and dairy calves is indicative of performance as it relates to carcass weights in beef (Hennessy and Morris., 2003) and milk yield in dairy cows (Soberon et al., 2012). Thus, in the Holstein x Angus crossbred calves enrolled in this study, the key indicator of performance utilized was ADG, which was variable among individuals over the total study period. Average daily gain (ADG) was similar to group housed Holstein calves in (Neave et al., 2019) and in individually housed Limousine x Holstein calves in (Vestergaard et al., 2019). Despite differences in breeds and management practices, there are nevertheless similar ADG between these studies.

Personality could explain some of the differences in ADG observed between individuals. Calves that scored highly on the personality trait “fearful” had a negative association with overall ADG. The relationship between fearfulness and growth is seen across several studies in growing calves. For example, young beef calves that were highly reactive (while in the chute and high flight speed exiting the chute) had decreased weaning weight (Francisco et al., 2012, Torres-Vazquez and Spangler., 2016). In post-weaned beef cattle, calm individuals (less fearful, determined from subjective chute

scores) have repeatedly been shown to have greater ADG (Voisinet et al., 1997) and feed efficiency (Reinhardt et al., 2009). In dairy calves, growth was also related to personality, where more "exploratory/active" calves in the novel environment test (Neave et al., 2018a), and more "bold" calves in novel person, object and startle tests were associated with higher average daily gains (Woodrum Setser et al., 2022). Research on personality of beef-on-dairy crossbred calves is limited, but there is similar evidence in crossbred cattle; individuals exhibiting less fearful behavior in a social separation test showed higher ADG (Müller and von Keyserlingk., 2006). Overall, despite the different housing systems, breeds, and personality tests across these studies, more fearful (or reactive) individuals appear to have poorer performance. This relationship may relate to calves being more reactive to changes in their environment such as daily handling that occurred and may be more cautious or vigilant toward their surroundings, leading to greater energy expenditure. These high arousal states from fearfulness may also affect feeding behavior and feed intake, consequently reducing growth.

2.5.3. Personality and Feeding Behaviors

There was also notable variation in feed intake and time spent eating per day among individual calves of this study; some of this variation could be explained by calves scoring highly on the "fearful" personality trait that were associated with reduced DMI. Solid feed intake was a major driver of calf success during weaning, as starter intake in calves promotes rumen development and reduces negative behaviors and growth check at weaning (as reviewed by Khan et al., 2011). Few studies have examined the relationships between personality traits and solid feed intake in calves, but there appears to be support for such associations. One study that fed dairy calves using an automatic grain feeder found more "exploratory/active" calves (scored from a novel environment test) were

positively associated with total starter intake and gain: feed ratio (Neave et al., 2018a), possibly because these calves were more likely to encounter or willing to sample alternate food sources while exploring their environment. The gain: feed ratio was not analyzed in our study but is worthy of investigation in future work, especially in crossbred calves. However, another study reported that "fearful" dairy calves (scored from novel human and object tests) were negatively associated with weaning age based on individual solid feed intake (i.e., more fearful calves consumed more DMI and weaned earlier; Neave et al., 2019). The authors speculated these calves may be more reactive to the removal of milk and respond by increasing solid feed intake to complete weaning earlier. In contrast, Angus beef steers that were more reactive to restraint in a chute and had greater flight speeds upon release (interpreted as more fearful) were associated with lower DMI at the feedlot (Cafe et al., 2011). These authors, among others (Petherick et al., 2002), have suggested this may be due to increased vigilant behavior and high arousal state leading to lowered feed intake; we suggest a similar mechanism may explain the reduced feed intake (and growth, as described above) in individually housed crossbred calves. Alternatively, a general reluctance of fearful calves to sample novel feeds (food neophobia; Costa et al., 2020) may drive this relationship. Overall, these studies provide evidence of a relationship between fearfulness and solid feed intake in both dairy and beef animals, although the mechanism behind this relationship remains to be explored.

Feeding behavior has also been shown to be influenced by personality of the individual (reviewed by Neave et al., 2018b). We found no association between time spent eating grain and "fearfulness" personality trait, despite this trait having associations with reduced grain intake and ADG. However, we did observe a tendency for a negative

association between time spent eating grain and “inactive” personality trait, yet this trait had no association with intake or ADG. These findings suggest that feeding rate (or bite size) may be a key influential behavior in calves of these personality traits. Eating time of solid feed has not been explored in young calves, but previous work in group housed dairy calves found stable and repeatable milk-feeding behavior patterns (Carslake et al., 2022). Individual differences in milk drinking speed (i.e., feeding rate) were related to “fearfulness” and visits to the milk feeder were related to “vocal/inactive” traits in calves using an automated milk feeder (Neave et al., 2018a; 2019). There may have been differences in milk feeding behaviors that were not measured in this study that may relate to personality of crossbred calves.

We measured other behaviors associated with the nutritional environment of calves, including water drinking duration and non-nutritive oral manipulation behaviors. Water drinking duration had no associations with any personality trait measured in this study; no previous work has explored variability in this behavior, water intake, or their possible relationships with personality, despite the importance of water for productivity and welfare in cattle (reviewed by Jensen and Vestergaard., 2021). A novel finding of this study was that non-nutritive oral behaviors in the home pen, specifically licking and sucking of feed or water buckets and fixtures, were expressed more in calves with higher scores for “inactive” personality. Non-nutritive oral behaviors are stimulated by ingestion of milk (De Passillé and Rushen., 1997), and these behaviors seem to be expressed more often in individual than group housed calves (Tapki., 2007), perhaps due to a lack of environmental complexity. These behaviors in our dairy-beef crossbred calves also occurred outside of milk feeding times, suggesting there may be underlying motivations

to perform this behavior that are not related to milk ingestion. The reason why calves of the “inactive” personality performed non-nutritive oral behaviors more than other individuals may relate to how these calves respond to changes in their environment. When exposed to the novel and startling situations during the personality tests, these calves remained inactive (standing idle, performing no other behaviors) or performed grooming behaviors, which may indicate an incapacity to respond appropriately to environmental stimulation in their home pen. A lack of behavioral response to novel or unexpected stimulation may indicate a break-down in attentional processes arising from housing in impoverished environments (Wemelsfelder and Future. UFAW, 1991) and this lack of arousal can be an indicator of boredom (Burn., 2017). The fact that calves of the “inactive” personality tended to also show reduced activity in the home pen (measured using motion index and steps from accelerometers) may further support inactivity as a reflection of boredom in these calves (Hintze et al., 2020). Consequently, redirected behaviors toward immediately available stimuli in the housing environment may arise from a need to ‘do something’ (Wemelsfelder and welfare, 1993) and we suggest this may have manifested in more non-nutritive oral behaviors in calves of the “inactive” personality. Special management, such as providing environmental stimulation, may be needed for these calves under individual housing conditions (da Silva et al., 2022). For instance, additions to the environment of individually housed calves can reduce the occurrence of non-nutritive oral behaviors, such as providing hay (Downey et al., 2022), stationary brushes (Horvath et al., 2020) or human contact (Doyle and Miller-Cushon., 2022). Activity patterns of calves in the home pen as a personality trait are rarely explored for links with other behaviors and performance, but the current study has

revealed its potential importance and how this measure can be easily collected with technology. Alternatively, the isolation box test (brief restraint in an enclosed, dark box) identifies an "activity" personality trait, and has associations with both home pen activity and weaning performance in dairy calves (Woodrum Setser et al., 2022).

2.5.4. Study Limitations

Behavioral responses to standardized tests should be consistent over time to be considered a personality trait (Carter et al., 2013). The novel person, novel object and startle tests used in this study have temporal consistency in dairy calves (Veissier et al., 1997; Van Reenen et al., 2004; Neave et al., 2020), but due to the terminal nature of the concurrent study we were unable to confirm temporal consistency of behavioral responses to these tests in our dairy-beef crossbred, individually housed calves. Future research should test the consistency of personality traits of dairy beef calves through rearing, puberty, and at market weight, as these traits may change at key development periods (Neave et al., 2020) but nonetheless still predict later performance as mature animals. We acknowledge that the individual pens of this study may be larger than the individual pens in commercial dairies and that it may influence behavior. However, there isn't a significance difference between the individual pens and may even not reveal any impact on the results. Research should be done utilizing the individual pens of commercial dairies to explore this. Finally, we acknowledge our measure of feeding, drinking and non-nutritive oral behaviors were limited to 4 days across preweaning, weaning and postweaning periods. Our study provides early evidence that variation in time spent engaged in feeding and non-nutritive oral behavior may be related to individual personality traits, which merits a more detailed investigation of how these behavioral patterns may predict calf performance at specific developmental periods.

2.6. Conclusion

Standardized personality tests conducted within the home pen were able to measure several personality traits in individually housed crossbred calves. These personality traits were able to explain some of the individual variation in ADG, grain intake, time spent feeding and time spent engaged in non-nutritive oral behaviors in the home pen. These results indicate that personality testing can predict performance and home pen behaviors of individually housed crossbred calves, similar to findings in group housed dairy calves. Given individual housing remains prevalent in calf rearing systems, these tests could potentially be used on these farms to identify particularly "fearful" calves that are slow to approach a novel object both before and after being startled. Testing could also be used to identify "inactive" individuals who spent more time engaging in non-nutritive oral manipulation of their environment. Both behavioral types may require targeted management to meet their behavioral needs and improve performance.

Table 2.1. Ethogram of behaviors recorded from the videos of the standardized personality tests (novel person, novel object, and startle tests) from individually housed Holstein x Angus crossbred calves (n = 29) tested in their home pen at 81.6 ± 2 d old.

Behavior	Definition
All tests	
Grooming	Duration of calf licking or scratching own body with mouth or muzzle, or scratching own body with any limbs
Resting	Duration of lying down, from the point the rear touches the ground until the point when the back legs are lifted to stand
Inactive	Duration of time spent with no movement, no interaction with the environment, and not attentive toward person or object
Walking	Duration of calf moving around the pen, excluding running or trotting.
Environment exploration	Duration of time calf spent exploring the walls, ground, and other fixtures of the pen with tongue and muzzle
Locomotor Play	Duration of time spent running, jumping, or trotting around pen
Object/Person Play	Duration spent butting or mock butting the novel person or novel object
Bucking	Number of events where the calf lifts both hind legs off the ground and kicks backwards
Withdrawal	Number of events where the calf takes a sudden step or multiple steps backwards
Urination/Defecation	Duration of time spent with the tail lifted to expel urine or feces
Novel Person test	
Latency to approach	Time from the moment the calf enters the home pen, to the time the calf's muzzle makes contact with the novel person
Touching Person	Duration of calf using muzzle to make contact with the novel person
Attentive to Person	Duration of time calf spent with head orientated towards person
Novel Object / Startle test	
Latency to initial approach	Time from the moment the calf enters the home pen, to the time the calf's muzzle comes in contact with the novel object
Latency to re-approach after startle	Time from the moment the car moves (start of startle) to the time the calf's muzzle touches the novel object again
Touching Object	Duration of calf using muzzle to make contact with the novel object
Attentive to Object	Duration of time calf spent with head orientated towards object

Table 2.2. Performance and feeding behavior data for each calf throughout the 76-day experimental period. Performance (ADG and DMI) is reported in kg/d and feeding behavior is reported in seconds.

Calf	ADG	DMI	Nonvisible	Eating	Drinking	Licking	Other
1	1.29	1.87	891	26.75	10.75	23.25	392.5
3	0.4	0.56	1266.5	30	5.5	25	15.75
4	1.07	1.56	1158	65.5	2.5	22.5	94.25
5	1.05	1.63	1238.75	40.25	8.5	11.5	39.75
6	0.64	0.76	1129.5	40.75	2.5	26	136.75
7	1.14	1.47	932.5	45	0.25	27.75	329.75
8	1.07	1.59	1220.75	33.75	3.25	35.25	42
9	0.99	1.45	1135.25	48.5	1.25	34	113.5
10	1.13	1.69	1201.25	38	5.75	30.5	56.25
11	0.99	1.21	1087	47.75	5.75	28.25	162
13	0.91	1.25	1132	34	9.25	28.75	124
14	0.88	1.19	1184.75	50	11	16.75	58.5
15	1.1	1.55	1203	45	1.75	24.25	48.75
16	1.02	1.66	1153.25	42.75	5.75	10.75	109
17	1.37	1.93	1230	36	7.75	13	57.25
18	1.16	1.30	1245.25	27	7	25.25	36.75
19	1.12	1.34	970.75	41.25	13.25	18	297.25
20	1.18	1.37	1187.75	25.5	5.75	24.25	98
21	1.2	1.49	1225.75	37.5	1.75	7.75	69.25
23	0.52	0.50	936.75	25.25	0.25	51	327.5
24	1.57	2.13	1215.25	42	10.75	24	49.25
25	0.99	1.09	994.25	63.5	0.5	14	269
26	1.32	1.76	997	31	3.25	42.25	267
27	0.67	0.87	985	27.33	2	43	291.67
29	0.76	0.53	1125.75	40	12.5	23	138.5
30	0.62	0.49	937.25	29.25	0	45.5	327.5
31	0.98	1.08	911.75	28	7.5	30.25	360.75
32	0.33	0.50	913.75	27	3.75	4.5	386.75

Table 2.3 Activity measures for each calf from the leg pedometer over the 76-day experimental period. Standing time and lying time are reported in seconds.

Calf	Motion_index	Standing_time	Lying_time	Steps	Lying_bouts
1	880.34	6:39:56	17:07:28	137.52	18.03
3	615.85	9:14:45	14:14:53	99.64	8.47
4	1302	6:05:14	17:09:44	263.88	23.17
5	1203.44	7:00:10	17:01:51	230.72	15.65
6	919.29	7:53:09	15:50:59	177.29	15.82
7	686325.51	4:21:57	20:35:06	36806	29.04
8	982.72	6:48:39	16:45:48	190.42	19.75
9	1088.41	7:45:02	15:57:12	181.95	17.46
10	1234.3	7:22:40	16:11:17	234.47	16.97
11	1010.66	5:58:53	17:21:36	180.82	19.53
13	990.92	5:43:52	18:00:21	211.04	17.9
14	922.1	7:07:40	16:12:56	172.05	16.16
15	1126.21	5:48:42	17:13:39	238.05	18.35
16	1282.63	7:08:31	16:22:28	244.36	18.17
17	1361.49	6:22:44	17:14:25	260.75	19.01
18	1462.4	6:03:41	17:15:45	227.1	22.39
19	983.33	7:05:49	16:22:34	170.16	14.98
20	912.72	6:59:06	16:41:57	161.22	15.63
21	947.33	4:58:03	18:38:56	172.79	18.93
23	443.72	5:43:41	17:43:45	70.51	16.78
24	1374.85	6:30:11	17:06:57	238.07	20.51
25	884.07	7:16:35	16:20:50	143.35	18.61
26	921.93	6:26:58	17:14:28	185.07	15.29
27	908.44	7:33:41	16:11:39	121.7	14
29	664.68	7:16:49	16:21:43	119.56	17.21
30	1046.74	6:11:31	17:22:34	166.47	19.35
31	770.24	6:36:47	16:43:23	116.99	14.4
32	270.27	6:30:24	16:56:47	34.16	12.88

Table 2.4. Behavioral responses of Holstein x Angus crossbred calves (n=29) during the standardized personality tests (novel person and novel object/startle tests) when tested individually in their home pen at 81.6 ±2 d old. Values are reported as mean, standard deviation, and range (in seconds).

Variable	Mean	SD	Range
Latency to approach novel person	7.3	12.7	1.0-70.5
Latency to initially approach novel object	77.9	112.8	1.7-300.0
Latency to re-approach novel object	187.7	121.8	5.4-300.0
Attentive to novel person and novel object [1]	233.1	142.9	41.8-499.4
Touching novel person and novel object [1]	313.6	116.1	159.9-682.4
Grooming [1]	6.5	7.8	0-37.8
Inactive [1]	129.0	94.7	25.5-365.0
Play [1, 2]	264.5	119.5	9.6-444.0
Exploring Environment [1]	37.1	30.9	0-136.5
Walking [1]	25.6	16.0	3.4-68.8
Bucking	0	0	0
Urinating/Defecating	0	0	0

[1] Total duration summed across the tests per calf, then averaged across calves.

[2] Total duration of locomotory play and object/person play

Table 2.5. Coefficients (loadings) of each variable for the first 3 factors extracted from the principal component analysis of the behavioral responses of Holstein x Angus crossbred calves (n = 29) in the standardized personality tests. The eigenvalues are reported for each factor and variables with high loadings ($\geq \pm 0.63$) are in bold. The labels given to each factor are subjective interpretations of the correlated set of behaviors with high loadings; each factor is interpreted as a personality trait.

Variable	**Factor 1**	**Factor 2**	**Factor 3**
Grooming	0.05	**0.83**	-0.09
Inactive	0.11	**0.82**	-0.01
Latency to approach novel person	0.47	0.33	-0.43
Latency to initially approach novel object	**0.86**	0.12	0.01
Latency to re-approach novel object	**0.88**	0.05	-0.04
Attentive to novel person or object	**0.95**	0.09	-0.02
Touching novel person or object	-0.20	-0.27	**0.85**
Object/Person Play	-0.38	-0.44	**-0.77**
Eigenvalues	3.24	1.50	1.35
Variance Explained	40.5%	18.8%	16.9%
Interpretation	**“Fearful”**	**“Inactive”**	**“Bold”**

Table 2.6. Relationships between factor scores (personality traits), performance and home pen behavior of individually housed Holstein x Angus crossbred calves (n = 29) during the 76-d experimental period.

Factor and variable	F-Value [1]	*P*-Value [2]
Factor 1 ("Fearful")		
Total ADG (kg/d)	**26.35**	**<0.0001**
DMI (kg/d)	**25.47**	**<0.0001**
Motion Index	0.29	0.59
Standing Time (h/d)	0.2	0.66
Lying Time (h/d)	0.44	0.51
Steps (steps/d)	0.31	0.58
Eating Time (min/d)	0.19	0.67
Drinking Time (min/d)	1.45	0.24
Licking Time (min/d)	0.11	0.74
Factor 2 ("Inactive")		
Total ADG (kg/d)	0.98	0.33
DMI (kg/d)	1.69	0.21
Motion Index	*3.70*	*0.068*
Standing Time (h/d)	0.01	0.94
Lying Time (h/d)	0.00	0.98
Steps (steps/d)	*3.67*	*0.069*
Eating Time (min/d)	*2.90*	*0.104*
Drinking Time (min/d)	0.00	0.96
Licking Time (min/d)	**7.43**	**0.01**
Factor 3 ("Bold")		
Total ADG (kg/d)	0.06	0.81
DMI (kg/d)	0.81	0.38
Motion Index	0.56	0.46

Standing Time (h/d)	0.00	0.97
Lying Time (h/d)	0.04	0.84
Steps (steps/d)	0.57	0.46
Eating Time (min/d)	0.08	0.78
Drinking Time (min/d)	0.94	0.34
Licking Time (min/d)	0.24	0.63

[1]Degrees of freedom (numerator, denominator) = 1,17

[2] Significant *P* values (≤ 0.05) are bolded, and tendencies (≤ 0.10) are italicized

Figure 2.1. Average daily gain (ADG) of individually housed Holstein x Angus crossbred calves (n = 29) during the 76-d experimental period, plotted against Factor 1 (“Fearful”) from the principal component analysis of the standardized personality tests. Each black dot represents a calf, and the linear regression trendline is presented ($P < 0.001$).

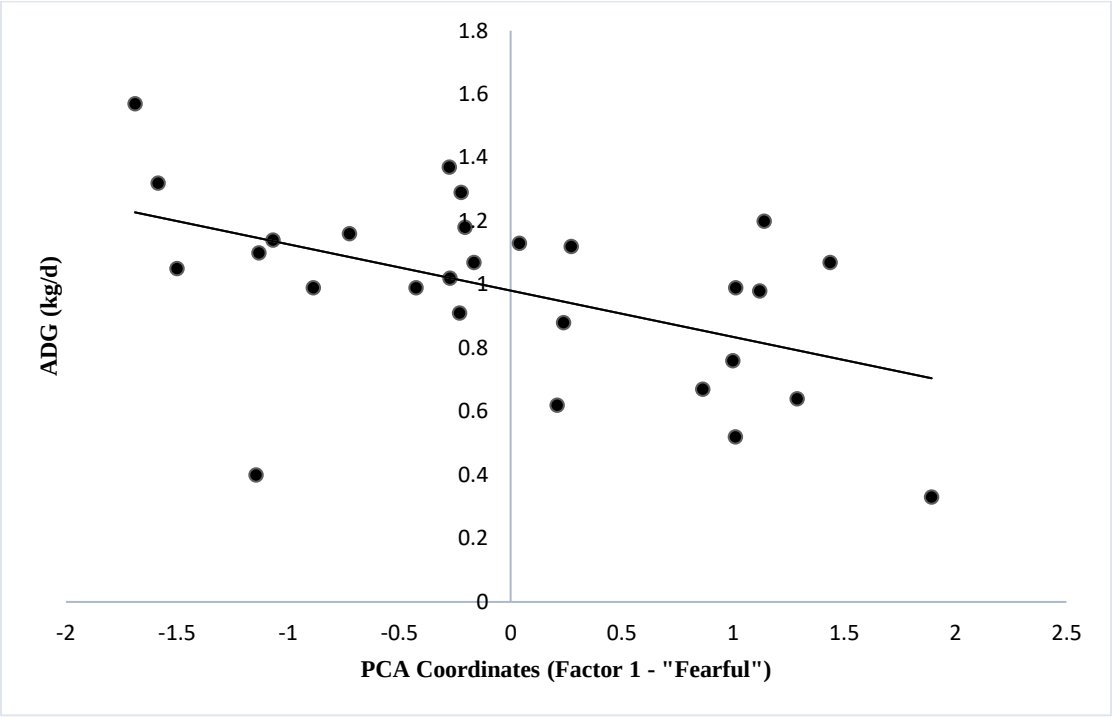


Figure 2.2**.** Average grain dry matter intake (DMI/d) of individually housed Holstein x Angus crossbred calves (n = 29) during the 76-d experimental period, plotted against Factor 1 ("Fearful") from the principal component analysis of the standardized personality tests. Each black dot represents a calf, and the linear regression trendline is presented ($P < 0.001$).

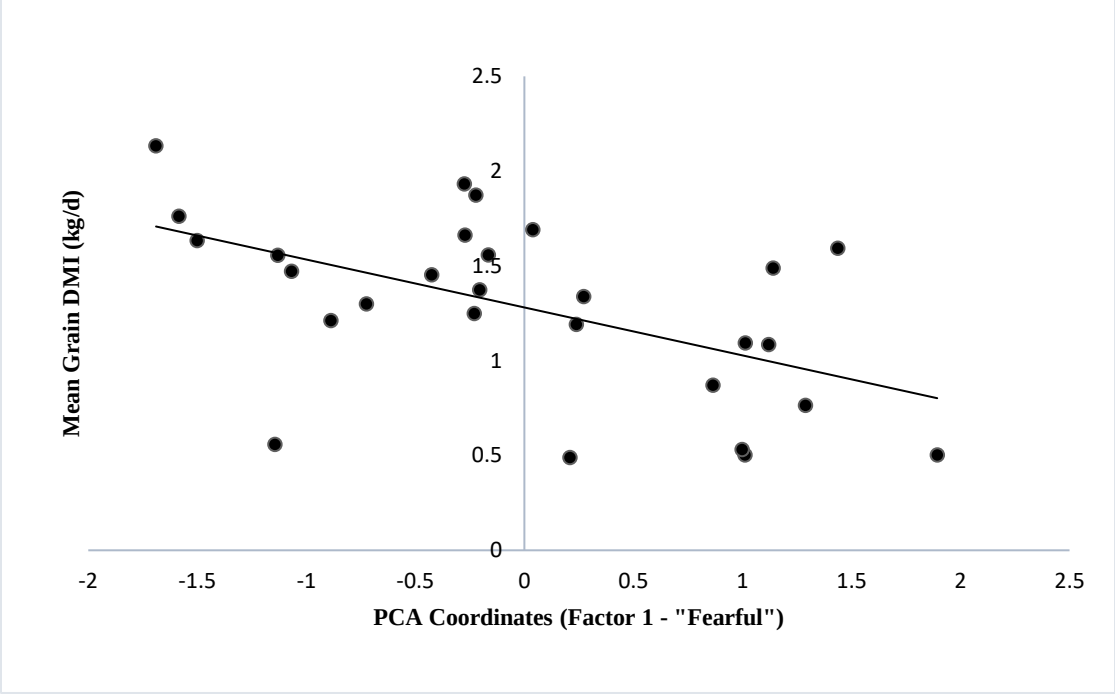
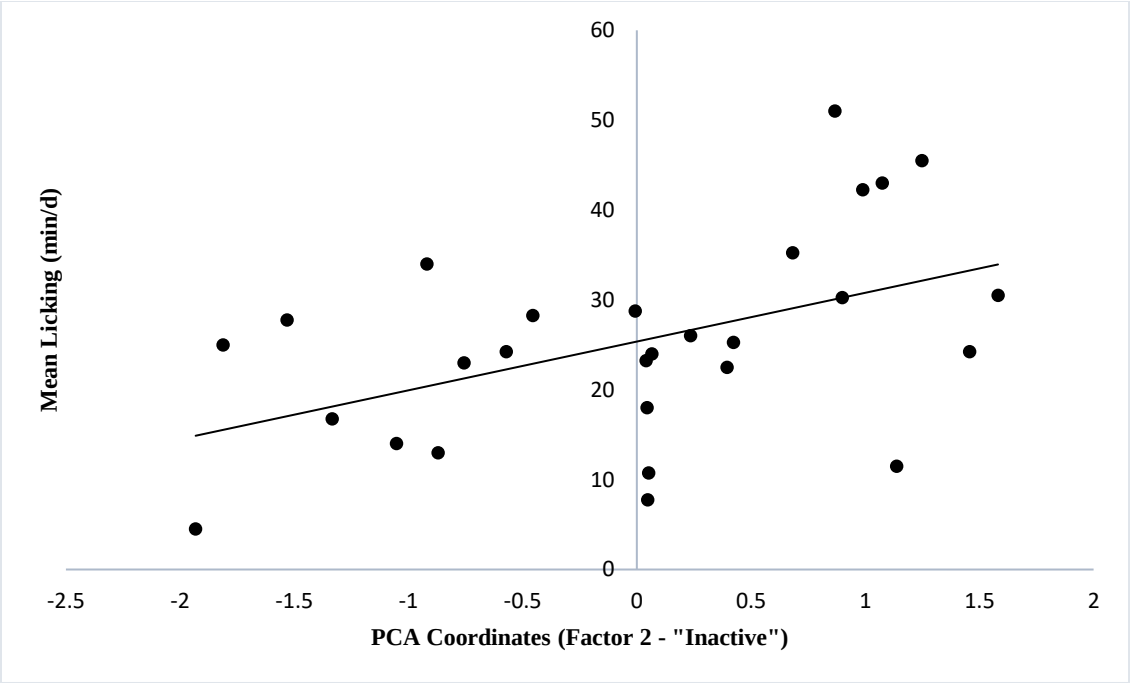


Figure 2.3. Average time spent licking (non-nutritive oral behavior in the home pen) of individually housed Holstein x Angus crossbred calves (n = 29) during the 76-d experimental period, plotted against Factor 2 (“Inactive”) from the principal component analysis of the standardized personality tests. Each black dot represents a calf, and the linear regression trendline is presented ($P < 0.001$).



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VITA

EDUCATION

Bachelor of Science in Animal Science
May 2021
Minor in Agriculture Economics
University of Kentucky
Lexington, KY

PROFESSIONAL POSITIONS

Graduate Research Assistant August 2021-Present
Department of Animal and Food Sciences
University of Kentucky

Research Intern August 2020-May 2021
Department of Animal and Food Sciences
University of Kentucky

SCHOLARSHIPS AND AWARDS

Maryland Sheep Breeder's Association Scholarship Recipient August 2017

Bluegrass Spirit Scholarship Recipient August 2017-May 2021

Placed in AVMA Graduate Team Animal Welfare Judging November 2021

Placed in AVMA Graduate Team Animal Welfare Judging November 2022

PUBLICATIONS AND PRESENTATIONS

PUBLICATIONS

Michalski E, Woodrum Setser MM, Mazon G, Neave HW and Costa JHC (2023). Personality of individually housed dairy-beef crossbred calves is related to performance and behavior. Front. Anim. Sci. 3:1097503. doi: 10.3389/fanim.2022.1097503

POSTER PRESENTATIONS

Michalski, E, Woodrum Setser, M, Mazon, G, Neave, H.W, Costa, J.H.C. 2022. Fear response and future performance: standardized personality testing is associated with performance in individually housed crossbred holstein X angus calves. Regional ISAE. Accepted.
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