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Feeding behaviour and activity of beef calves during the first week at the feedlot: Impact of calf source and commingling ratios

Abigail Hodder [a,*], Ed Pajor [a], Frank van der Meer [a], Julia Louden [a], Sean Thompson [b], Karin Orsel [a]

[a] Department of Production Animal Health, Faculty of Veterinary Medicine, University of Calgary, 3280 Hospital Drive NW, Calgary, AB T2N4Z6, Canada

[b] Technology Access Centre for Livestock Production, Olds College Centre for Innovation, Olds College, 4500 50th Street, Olds, AB T4H 1R6, Canada

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ABSTRACT

Preconditioned (PC) calves have reduced morbidity, mortality and improved performance compared to auction-derived (AD) and non-preconditioned calves; however, there is limited research on the impacts of commingling PC and AD calves at the feedlot. Commingling calves from various sources is known to be highly stressful and can impact performance on arrival at the feedlot. Therefore, the first objective was to assess feeding behaviour (time spent eating and ruminating) and activity of PC beef calves during the first 7 days after arrival at the feedlot compared to ranch-sourced (RS) and AD calves. The second objective was to assess the impacts of commingling PC calves with various proportions of AD calves (25, 50, 75 %) on feeding behaviour and activity in that same time frame. A subset of 45 calves per pen for PC, AD, and commingled pens, and 20 RS calves were equipped with CowManager® tags on arrival. This technology detects ear movement through a sensor in the tag linked to eating, ruminating, active and not active. On average, in the first 7 days at the feedlot, PC calves spent 11 % more time eating than RS and 15 % more time than AD calves. PC calves spent 5 % less time active compared to RS ($P < 0.000$), and there was no significant difference in activity compared to AD. PC calves spent 4 % less time not active compared to RS ($P = 0.017$) and 15 % less time inactive compared to AD calves ($P < 0.001$). There was no difference among PC, RS and AD in overall time spent ruminating. When comparing PC calves from 100 % PC and commingled pens, 100 % PC calves spent 5 % more time eating compared to a 75 % ratio PC and 5 % more time eating compared to a 25 % ratio PC pen. However, time spent eating was not significantly different between 100 % PC and 50 % ratio PC. Furthermore, PC calves had increased time spent eating and less time spent active and not active during the first 7 days after arrival at the feedlot compared to RS and AD calves. When commingled with AD calves, PC calves had more time spent eating and reduced time spent active and not active; therefore, PC calves have exhibited increased feeding behaviour also after being commingled with AD calves at the feedlot. The current study acknowledges the limitations of the field experiment that not all confounding variables could be controlled for, explicitly pen effect due to the lack of replication of pens across groups.

1. Introduction

Calves transitioning from the ranch to the feedlot undergo numerous stressors within a short time frame, including weaning, transportation, and adapting to new environments and feed sources (Taylor et al., 2010; Cooke, 2017). Introducing calves to new environments can lead to stress-related immune suppression which can be detrimental to animal health and welfare. For example, these transitioning stressors can increase the risk of bovine respiratory disease (BRD), the leading cause of morbidity and mortality in North American feedlot cattle (Ball et al., 2019). These transitioning stressors can also lead to a decreased feed intake for up to 2 weeks on arrival (Duff and Galyean, 2007), whereby the most pronounced decreases are associated with higher morbidity (Hutcheson and Cole, 1986; Sowell et al., 1998).

Practices to reduce transitioning stress during the ranch phase include gradual weaning strategies, early castration, and pre-exposing calves to a feedbunk, commonly referred to as preconditioning. The goal of preconditioning is to avoid the clustering of stressful interventions (Enríquez et al., 2010; Hilton, 2015). Until weaning, cows and calves are commonly kept together on pasture, and the source of

* Corresponding author.
E-mail address: hodder.abby@gmail.com (A. Hodder).

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nutrients for the calf is the dam's milk, plus grazed forage. Consequently, when calves arrive at the feedlot, they have no prior experience consuming feed from a feed bunk (Lynch et al., 2010). Preconditioned (PC) calves which experienced eating from a feedbunk at the ranch, the feedbunk faster on arrival compared to calves lacking this feedbunk experience (Walker et al., 2007).

Risk factors for morbidity and mortality include commingling calves from various sources upon arrival, and with typical feedlot management, it is often not possible to keep calves from multiple sources separate (Loerch and Fluharty, 1999). Although morbidity and mortality are common indicators of health in feedlots, other parameters such as feeding behaviour and activity can be used to assess the impact of transitioning stressors on the calves on arrival at the feedlot (Llonch et al., 2018; Marchesini et al., 2018). There is currently no research assessing the impacts of commingling PC and AD calves at the feedlot and if the proportions of PC to AD calves in commingled pens impact feeding behaviour at the feedlot. For example, if a pen has a larger ratio of PC calves experienced with a feed bunk, this may increase the activity of AD calves at the feed bunk, compared to AD calves in a pen with fewer PC calves.

The first objective of this field study was to assess the impact of source (PC, AD, and calves sourced directly from the ranch (RS)) on feeding behaviour (time spent eating and ruminating) and activity of beef calves during the first 7 days after arrival at the feedlot, with RS calves being from the same source as PC, but abruptly weaned and not commingled. The second objective was to assess the impact of commingling PC calves with different proportions of AD calves (25, 50, 75 %) on feeding behaviour and activity during the first 7 days at the feedlot. We hypothesized that a higher proportion of PC calves per pen would result in an increase in time registered "eating" and "ruminating" and a decrease in time registered "active" compared to RS and AD calves, with no difference in time registered "eating", "ruminating" and "active" of RS calves compared to AD calves during the first 7 days after arrival at the feedlot. We also hypothesized that PC calves, despite commingling ratios, would have the same time registered "eating" and "ruminating" and a decrease in time registered "active".

2. Methods

This study was approved by the University of Calgary Veterinary Services Animal Care Committee (AC20–0041) and complied with the Canadian Council on Animal Care guidelines. Preconditioned and RS calves used in this experiment were derived from WA Ranches at the University of Calgary, whereas AD calves were purchased from a presort at a commercial sale market in Olds, AB.

2.1. Animals

The first 250, Angus-cross male calves born at WA ranches were enrolled in the study and raised under a preconditioning protocol as described below. Exclusion criteria were twins, calves born from heifers or calves treated with antimicrobials early in life. Birthweight was not included as a selection criterium.

An additional 20 Angus-cross male calves from WA Ranches at the University of Calgary were enrolled as controls and referred to as ranch-sourced (RS). These calves were born from cows that were selected to be culled and therefore grazed in a separate management group.

Upon arrival at the feedlot, 250 CE steer calves were pre-sorted at the auction market based on the similarity of frame and weight to the PC calves that were enrolled. No information was available regarding AD vaccination status or weaning methods.

2.2. Experimental design

2.2.1. Ranch phase

2.2.1.1. Preconditioned calves. Cow-calf pairs were on pasture during and after calving until weaning in September 2020 (Fig. 1). At birth, calves were given an intranasal vaccine (INFORCE 3, Zoetis, Kirkland QC Canada). During processing, at ~60 days of age, calves were knife castrated and given oral meloxicam (Metacam, Boehringer Ingelheim, Burlington ON, Canada), vaccinated to protect against common BRD pathogens and clostridial diseases, and received a growth-promoting implant (Synovex C, Zoetis, Kirkland QC, Canada). Calves were checked twice daily by ranch staff for illness, if two or more clinical signs of BRD (cough, difficulty breathing, runny nose, or droopy ears) were observed, the body temperature was measured (McMullen et al., 2019). If the temperature was >40 °C, calves were treated based on the ranch treatment protocol recommended by the veterinary consulting clinic.

During the last week of September 2020 at 5–6 months of age, preconditioned calves were vaccinated with Bovi-Shield Gold One Shot (Zoetis Canada, Kirkland, QC) and ULTRABAC 7/SOMUBAC (Zoetis Canada, Kirkland, QC). Calves were fenceline weaned for 5 days, which involved separating cows and calves by an electric fence, so calves could not suckle but had visual and auditory contact with their dams. Calves had access to pasture and hay on the ground to help acclimatize to a non-milk diet and water troughs as a water source.

In early October, five days after the start of the fenceline weaning process, calves were relocated to a pasture pen on the main ranch. This pen had water troughs and feed bunks to expose calves to supplemental feed delivered in a bunk. On arrival at the pasture pen, calves had access to grazing and hay on the ground. Feedbunks, comparable to those at the feedlot, were 50 m long and 48 cm deep, allowing 46 cm of head space. Feed (Table 1) was formulated to be comparable with the starting ration at the feedlot and delivered via feed truck, with the amount adjusted based on the feed remaining. Calves remained at this location for 40 days until transportation to the feedlot.

2.2.1.2. Ranch-sourced calves. Cow-calf pairs in this group were separated from the rest of the herd. At birth and during processing, at 60 days of age, calves received the same vaccinations as PC calves. Cow-calf pairs were on pasture until abrupt weaning on the day of transportation in November 2020.

2.2.2. Feedlot phase

2.2.2.1. Auction-derived calves. Auction-derived calves were purchased on November 13th and 14th, transported to the feedlot over a short distance (approximately 2 km) and placed into pens on the day they were purchased. The weaning history for AD calves was unknown.

2.2.2.2. Procedures. In November 2020, PC and RS calves from the ranch were directly transported to a research facility 65 km away in southern Alberta (Olds). The RS calves (n = 20) were transported using a small trailer, whereas PC calves (n = 250) were transported in standard cattle liners. In addition, standard cattle liners were also used for the 2 km transportation of AD calves (n = 250). Receiving protocols upon the day of arrival at the feedlot for all calves were in line with industry standards and included recording weight, administering vaccinations, antiparasitic treatment and growth-promoting implants. However, calves were not given antimicrobial metaphylaxis on arrival. Calves were screened by feedlot staff for BRD, which included examination for clinical signs (cough, difficulty breathing, runny nose, droopy ears, etc.). After the receiving protocol was carried out, calves were placed into six pens (Table 2). On the morning of November 10th, the 100% RS pen was filled. On November 13th, PC calves filled the 100 % PC pen and the 50 %PC:50 %AD pen. In the afternoon of November

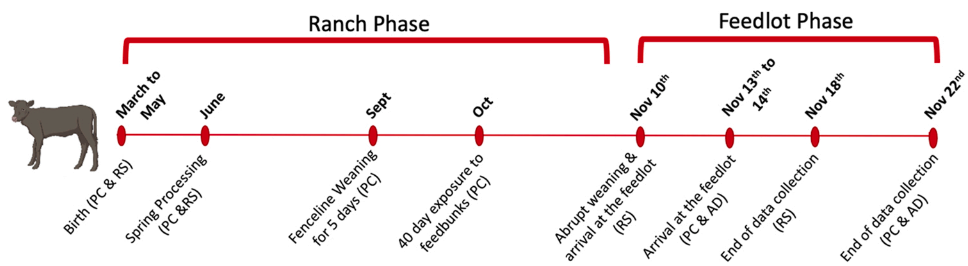

Fig. 1. Timeline from birth to arrival at the feedlot of preconditioned (PC), ranch-sourced (RS) and auction-derived (AD) calves.

Table 1
Detailed feed analysis of the ration provided to calves during preconditioning and feedlot (value in kg).

Item	Preconditioning (%)	Feedlot (%)
Ingredient composition, % of dry matter (DM)		
Barley silage	83.4	80.03
Barley grain	9.5	13.37
cDDGS[a]	3.8	3.2
32:12 Supplement M440[b]	3.3	3.4
Nutrient analysis[c]		
Crude protein, % of DM	11.6	12.5
Calcium, % of DM	1.1	0.51
Phosphorus, % of DM	0.29	0.32
Net energy for maintenance Mcal/lb	0.69	0.80
Net energy for gain Mcal/lb	0.42	0.51

[a] Corn distillers dried grains with soluble is a by-product of bioethanol fermentation, which uses the dry milling technology for starch-rich grains such as corn (Iram et al., 2020)
[b] Masterfeeds, Canada
[c] Analyses conducted by Cumberland Valley Analytical Services (Waynesboro, PA)

Table 2
Ratio of calves per pen and CowManager® tag allocation at the feedlot for preconditioned (PC), auction-derived (AD), and ranch-sourced (RS) calves.

Pens (ratio of calves per pen)	CowManager® tag allocation		
	PC	AD	RS
Pen 1 (100 % AD)		45	
Pen 2 (25 % PC 75 % AD)	11	34	
Pen 3 (50 % PC 50 % AD)	23	22	
Pen 4 (75 % PC 25 % AD)	34	11	
Pen 5 (100 % PC)	45		
Pen 6 (100 % RS)			20

13th, AD calves filled the 100 % AD pen and the 50 %PC:50 %AD pen. On November 14th, the remaining 25 %PC:75 %AD and 75 %PC:25 % AD pens were filled. Calves were fed a mixed ration via feed truck at 08:00 and 15:00. On the day calves entered the pens, no feed was delivered until 15:00, corresponding to the moment the pens were filled. Each pen had a dirt floor with a straw pack, waterers, and feed bunks. The pens with the PC and AD calves had windbreakers but no shelter. The pen for the RS calves had no windbreaks and was partly covered with a shelter. All pens were provided space as suggested by the code of practice, more specifically, the bunk space was equal in all pens and 18 in. per head and provided bunk allowance for 65 % of the calves in the pen.

2.3. Data collection

During the processing of calves on arrival, a subset of calves was equipped with an ear tag sensor that continuously recorded ear movement detected by an accelerometer located in the ear tag (Cow Manager® SensOor system, Agis Automatisering BV, Harmelen, the Netherlands). Behaviours recorded were eating (rapid, continuous ear movement associated with chewing and swallowing of feed), ruminating (ear movement associated with regurgitation, rumination, salivation, and swallowing of ingesta in a standing or lying position), active (any movement not including eating and rumination), and not active (no movement including eating, ruminating and activity). Sensors in the ear tag collected the data through a router that was sent to a computer and stored for analysis. This system was validated for use in beef calves (Wolfger et al., 2015). A stratified tag allocation was used for PC and AD calves, where every second calf was equipped with an ear tag sensor until the total number of tags for each pen were allocated. For RS calves all calves were equipped with an ear tag sensor (Table 2).

Recorded ear movements were presented in minutes for each hour (60 min) for 24 h (1440 min) per day. These movements were interpreted by an algorithm in specific behaviours: eating (rapid, continuous ear movement associated with chewing and swallowing of feed), ruminating (ear movement associated with regurgitation, rumination, salivation, and swallowing of ingesta in a standing or lying position), active (any movement not including eating and rumination), and not active (no movement including eating, ruminating and activity). Highly active observations were merged with active, as the validation for highly active is on an animal level to detect estrus in heifers.

2.4. Statistical analyses

A multilevel mixed effect negative binomial regression was used to analyze the relationships between time spent eating, ruminating, and activity (active, not active) and pen (calf source) per day for the first 7 days on feed. Data from calves treated with antimicrobials or which became sick within the first 7 days after arrival were excluded from the analysis. Data remained as a count for total time spent for each behaviour per day of individual calves per pen. Fixed effects included pen and day; calf registration ID was the random effect nested within pen. A negative binomial was used to account for excess zeros in the data, which did not follow a normal distribution nor presented homogeneity of variance. Non-significant variables and interactions ($P > 0.05$) were removed from the final models. For the second objective, comparing PC calves between pens commingled at different ratios, only PC calves of each pen were included in the analysis. Data was presented as a percentage and was calculated by adding the number of minutes for each behaviour performed per day, divided by the total minutes per day, to determine the percentage of time spent on each behaviour per day and over 7 days. All statistical analyses were performed using Stata (V 17; StataCorp LP, College Station TX, USA).

3. Results

One AD calf from the 25 %PC:75 %AD pen and two calves from the 100 % AD pens were diagnosed and treated for BRD within the first 7 days on feed, calves remained in the pen, but feeding data were excluded from the analysis. The final models for each behaviour (eating, not active, active and rumination) are presented with significant variables and interactions only, which are, for eating the variable pen, not active included the variables pen and day, rumination and active included all variables and interactions.

3.1. Comparison of behaviours of calves in pens of 100 % preconditioned, ranch-sourced, and auction-derived calves

During the first 7 days after arrival at the feedlot, PC calves registered 11 % (163.3 min/day) more time eating compared to RS ($P < 0.001$) and 15 % (213.7 min/day) more time eating compared to AD calves ($P < 0.001$). Ranch-sourced calves spent 4 % (50.4 min/day) more time eating compared to AD ($P < 0.001$). For activity, PC calves registered 5 % (62.7 min/day) less time active compared to RS ($P < 0.001$), and there was no difference in activity between PC and AD calves. Ranch-sourced calves spent 6 % (66.8 min/day) more time active compared to AD ($P < 0.001$). For time spent not active, PC calves registered 4 % (60 min/day) less time inactive compared to RS ($P = 0.017$) and 15 % (218 min/day) less time inactive compared to AD calves ($P < 0.001$). Ranch-sourced calves registered 11 % (158 min/day) less time inactive compared to AD ($P < 0.001$). There was no difference between PC, RS and AD in overall time registered ruminating. No temporal increase or trends among PC, RS and AD were identified throughout the week; however, on certain days, there were significant differences for time spent eating, active and not active. The mean daily time (percent) per behaviour is presented in Fig. 2.

3.2. Pen-level comparison of ratios of commingled preconditioned and auction-derived calves

The daily mean percent time by behaviour is presented in Fig. 3. Overall, the pen average of 25 %PC:75 %AD pen registered 6 % (118.1 min/day) less time eating compared to the 50 %PC:50 %AD pen ($P < 0.001$) and 2 % (95.4 min/day) less time eating compared to the 75 %PC:25 %AD pen ($P < 0.001$). There was no difference between the 50 %PC:50 %AD and 75 %PC:25 %AD pen for time registered eating. For time registered not active, the 25 %PC:75 %AD pen registered 7 % (154.1 min/day) more time not active compared to the 50 %PC:50%AD pen ($P < 0.001$) and 2 % (131.7 min/day) more time not active compared to the 75 %PC:25 %AD pen ($P < 0.001$). There was no difference for time registered not active between the 50 %PC:50 %AD and 75 %PC:25 %AD pen. There was no difference between all pens for time registered ruminating and time spent active.

3.3. Impact of commingling on time spent eating of preconditioned calves

Including only the PC calves from the 100 % PC and commingled pens in the analysis, the PC calves in the 100 % PC pen registered 5 % (66.1 min/day) more time eating compared to PC calves in the 75 % PC

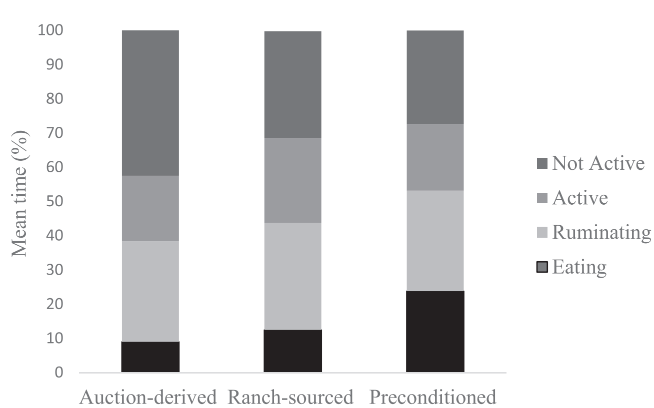

Fig. 2. Mean percent time spent eating, ruminating, active and not active of ranch-sourced,.
auction-derived, and preconditioned calves in the first 7 days at the feedlo.

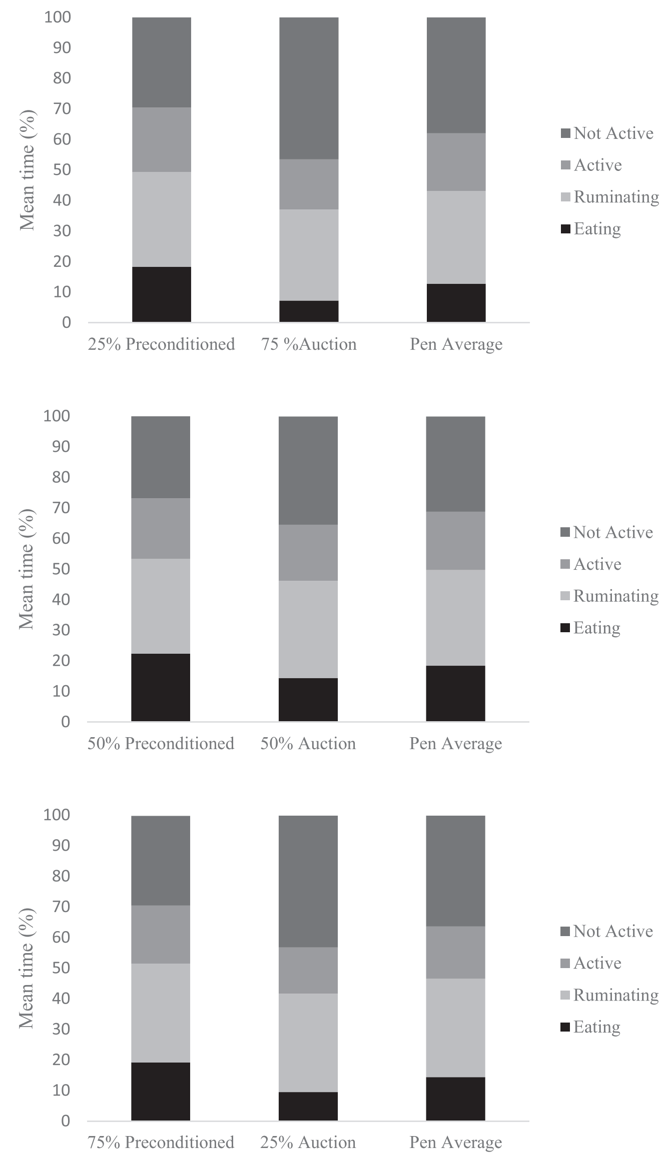

Fig. 3. Time spent eating of preconditioned and auction-derived calves commingled within a pen during the first 7 days at the feedlot.

pen ($P = 0.009$) and 5 % (78.2 min/day) more-time eating compared to PC calves in the 25 % PC pen ($P = 0.002$). There was no significant difference in time registered eating between PC calves from the 100 % PC and 50 % PC pen. Calves in the 50 % PC pen registered 4 % (57.6 min/day) more time eating compared to calves in the 25 % PC pen ($P = 0.021$). There was no difference in time registered eating for calves in the 75 % PC pen compared to 50 % PC or 25 % PC pens. The mean percent time registered eating per day between pens is presented in Fig. 4. For time registered ruminating, active and not active, there was no significant difference among PC calves from the 100 % PC, 75 % PC, 50 % PC and 25 % PC pens. The daily mean percent time by behaviour is presented in Fig. 5. No temporal increase or trends were identified throughout the week.

3.4. Impact of commingling on behaviours of auction-derived calves

Including only AD calves from the 100 % AD and commingled pens in the analysis, the AD calves in the 50 % AD pen registered 5 % (70.8 min/day) more time eating compared to calves in the 25 % AD pen ($P = 0.033$), 7 % (102.9 min/day) more-time eating compared to calves in the 75 % AD pen ($P = 0.001$) and 5 % (78.4 min/day) more-time

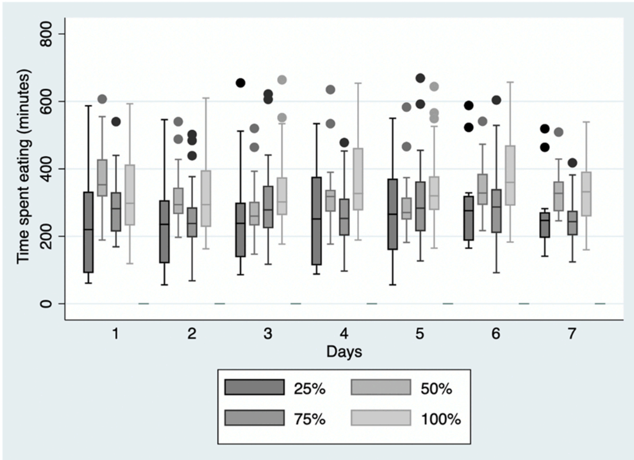

Fig. 4. Time spent eating in minutes per day for only preconditioned calves from each of the commingled pens (of 25 %, 50 %, 75 % and 100 %) in the first 7 days at the feedlot.

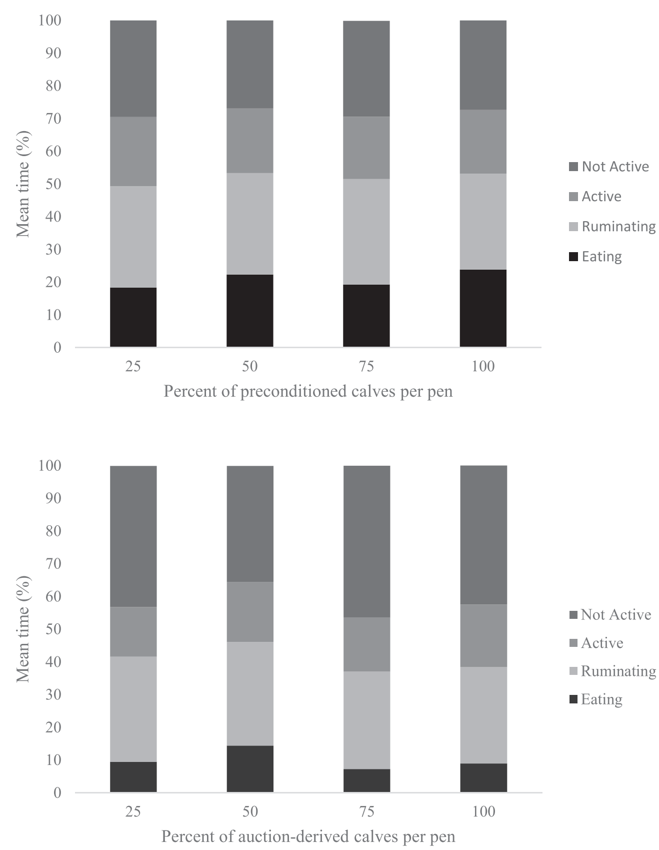

Fig. 5. Mean percent time spent eating, ruminating, active and not active of preconditioned and auction-derived calves from 25 %, 50 %, 75 % and 100 % preconditioned pens, in the first 7 days at the feedlot.

eating compared to calves in the 100 % AD pen ($P = 0.001$). There was no significant difference in time registered eating among AD calves from the 100 % AD, 25 % AD and 75 % AD pens. For time registered active, the 100 % AD pen spent 3 % (38.5 min/day) more time active compared to the 75 % AD pen ($P < 0.001$) and 4 % (58.7 min/day) more time active compared to the 25 % AD pen ($P < 0.001$). There was no difference between the 100 % AD and 50 % AD pens for time registered active. The 50 % AD pen spent 3 % (47.1 min/day) more time active compared to the 25 % AD pen ($P < 0.035$). There was no difference in time registered active for the 75 % AD pen between the 25 % AD and 50 % AD pens. For time registered not active, the 100 % AD pen spent 4 % (55.6 min/day) less time not active compared to the 75 % AD pen ($P < 0.069$) and 7 % (101.8 min/day) more time not active compared to the 50 % AD pen ($P < 0.001$). There was no difference in time registered not active between the 100 % AD and 25 % AD pens. The 50 % AD pen registered 8 % (111.6 min/day) less time not active compared to the 25 % AD pen ($P < 0.008$) and 11 % (157.4 min/day) less time not active compared to the 75 % AD pen ($P < 0.001$). There was no difference between the 25 % AD and 75 % AD pens for time registered not active. There was no significant difference among AD calves from the 100 % AD, 75 % AD, 50 % AD, and 25 % AD pens for time-registered ruminating. The daily mean percent time by behaviour is presented in Fig. 5. No temporal increase or trends were identified throughout the week.

3.5. *Within-pen comparison of preconditioned and auction-derived calves*

The daily mean percent time by behaviour is presented in Fig. 2. When analyzing differences between PC and AD calves within commingled pens, within the 25 %PC:75 %AD pen, PC calves registered 11 % (159.3 min/day) more time eating compared to AD pen mates ($P < 0.001$). For activity, 25 % PC calves registered 5 % (67.8 min/day) more time active compared to AD calves ($P < 0.001$). For time registered as not active, 25 % PC calves spent 17 % (242.5 min/day) less time not active compared to AD calves ($P < 0.001$).

Within the 50 %PC:50 %AD pen, PC calves registered 8 % (114 min/day) more time eating compared to AD calves ($P < 0.001$). For activity, 50 % PC calves registered 2 % (20.2 min/day) more time active compared to 50 % AD calves ($P = 0.023$). For time registered not active, 50 % PC calves spent 9 % (122.9 min/day) less time not active compared to the 50 % AD calves ($P < 0.001$). There was no significant difference between PC and AD calves for time-registered ruminating.

Within the 75 %PC:25 %AD pen, PC calves registered 10 % (140.1 min/day) more time eating compared to AD calves ($P < 0.001$). For activity, the 75 % PC calves registered 4 % (56.5 min/day) more time active compared to 25 % AD calves ($P < 0.001$). For time registered not active, 75 % PC calves spent 14 % (199.8 min/day) less time not active compared to 25 % AD calves ($P < 0.001$). There was no significant difference between PC and AD calves for time-registered ruminating. No temporal increase or trends were identified throughout the week between PC and AD calves.

4. Discussion

Preconditioned calves spent significantly more time eating in comparison to the RS and AD calves. Although time spent eating is not a direct measure of feed intake, other studies reported that PC calves consumed more feed in comparison to RS calves (Pritchard and Mendez, 1990; Walker et al., 2007). Similar results were reported in a transportation study where PC calves had a higher feed intake, rate, and meal duration in the first 3 days after arrival at the feedlot (Meléndez et al., 2021). Preconditioning calves at the ranch included exposure to a feedbunk, preparing calves for feeding management in the feedlot environment, and improved time spent eating, which could lead to increased consumption. Preconditioned calves registered almost twice the amount of time spent eating compared to AD calves. Gibb et al. (2000), recorded the average time steers spent eating at the feedlot to be 95.5 min/day from day 4 to day 7 and 115.9 min/day from day 8–14 at the feedlot (Gibb et al., 2000). This was comparable to the current study, where AD calves spent an average of 129.4 min/day eating. Comparisons must be made carefully, as recording time spent eating depends on the age of calves observed, weather, study design and bunk space availability.

Preconditioned calves were commingled in various ratios with AD calves to determine if there were impacts on feeding behaviour. Differences in time spent eating varied among PC calves depending on the proportion of AD calves in the pen; however, not in a consistent fashion. For example, the pens with 25 %PC:75 %AD and 75 %PC:25 %AD calves spent less time eating compared to 100 % PC and 50 %PC:50 %AD pens. Variables that may explain differences in feeding behaviour may include changes in the structure of social groups within commingled pens. Dominance rank can negatively impact feed intake of beef calves when first commingled in a group (Huzzey et al., 2006; González et al., 2008; Gibbons et al., 2009). Haskell et al. (2019) found that elements of social behaviour and temperament of individual animals had more impact on dominance and feed intake (Haskell et al., 2019). Unfortunately, this study did not collect data on social behaviour or assess temperament and therefore we cannot attribute the differences in time spent eating of PC calves within or between commingled pens to social facilitation. Calves with a larger frame and weight can influence dominance; although AD calves were sourced to be comparable in frame and weight of PC calves, PC calves weighed an average of 25 lbs. more than AD calves and therefore could have an impact on time spent eating within commingled pens (Brown et al., 2015). Preconditioned calves differed in time spent eating overall, when comparing AD and PC calves within commingled pens, PC calves had spent more time spent eating compared to AD calves in each pen. This increase in could be due to preconditioning practices at the ranch (Bailey et al., 2015; Campistol et al., 2016).

The RS calves in this study were transported directly to the feedlot and kept as a stable social group, compared to AD, which were transported at least twice and potentially mixed with other cattle at the auction before arrival. Commingling calves multiple times increases the disruption of pre-existing social groups, which can impact feed intake and performance (Bouissou, 2001; Wiegand et al., 2020). In the first 7 days at the feedlot, RS spent more time eating in comparison to AD calves which differs from a study by Gibb et al. which found no difference between AD and RS animals (Gibb et al., 2006). However, the difference was only 3.5 %, which may not be biologically relevant.

There was a decrease in time spent active for PC compared to RS calves. Increased activity in abruptly weaned calves may be attributed to searching for their dam (Haley et al., 2005). Therefore, an increase in activity in the RS calves could be a response to abrupt weaning before transportation. However, in AD calves, there was no significant difference in activity observed in comparison to PC calves. These results were not expected since 49–70 % of cow-calf producers in western Canada abruptly wean calves before sending them to the auction (Moggy et al., 2017; Western Beef Development Centre, 2017, 2017, 2017, 2018). In the current study, previous weaning strategies for AD calves were not available, therefore there was no apparent explanation for no differences in activity for AD and PC calves. CowManager® technology records "not active" when an animal is standing or lying while not ruminating, consuming feed or performing any activity (Pereira et al., 2018). Auction-derived calves spent 42 % of the day not active, which falls within the expected range (40 % and 55 %) (Hoffman and Self, 1973; Robért et al., 2011). However, RS calves spent only 31 % of the time not active and were 25 % of time active. Perhaps this was due to the location of the RS pen; calves were placed directly next to a pen with mature cows. Although incorporating a mature cow in feedlot pens did not influence calf health or performance of recently weaned calves, Gibb et al. (2000) found that when an older cow was present in a pen, calves were observed walking more in comparison to lying (Gibb et al., 2000). Therefore, although cows were not placed within the RS pen, being in proximity could have reduced inactivity in calves compared to PC. Furthermore, RS calves arrived at the feedlot three days before AD and PC calves. On the day of arrival, there was a snowstorm in the evening; however, data collection did not begin until the following day. During data collection for PC, RS and AD calves, there were no severe weather conditions that could explain unexpected variations in outcomes.

There was no difference in time spent ruminating between and within all pens, despite significant differences in time spent eating. The amount of time cattle spent ruminating varies and is dependent on factors such as diet, including feed composition, amount fed and adapting to concentrate from forage-based diets (Brown et al., 2015; Beauchemin, 2018). Despite differences in time spent eating, time spent ruminating may not be based on overall dry matter intake; therefore, there may be another explanation for there not being a significant difference in rumination time among pens, regardless of the increase in feeding time of PC calves (Gentry et al., 2016). Although AD calves spent less time eating compared to PC calves, adjusting to concentrate and smaller particle size can increase time spent ruminating, resulting in equal rumination time, despite a difference in time spent eating (Beauchemin, 1991; Llonch et al., 2020). Changes in diet from forage to concentrate can alter the composition of the ruminal microbiome (Khafipour et al., 2009; Petri et al., 2013). Similarly, housed dairy cows with decreased time spent eating due to feed composition or restriction had increased time spent ruminating (Campling and Morgan, 1981). It is speculated that PC calves may have been able to adjust to a concentrate diet at the ranch, which allowed for more time spent eating and a more efficient rumen microbiome at the feedlot, accounting for the lack of a significant increase in time spent ruminating.

The current study acknowledges the limitations of the field experiment that not all confounding variables could be controlled for, explicitly pen effect due to the lack of replication of pens across groups. Future studies should replicate commingled groups to improve external validity and to further determine how different ratios of PC calves commingled in a pen impact feed intake and activity. Additionally, data on social behaviour or temperament were not collected in this study; therefore, incorporating these data in future studies could explain the differences in time spent eating of PC calves between commingled pens. In addition, studies could include AD calves with known vaccination and weaning history to compare with RS and PC calves to ensure AD calves were not sourced from a ranch that used preconditioning practices.

5. Conclusion

To our knowledge, this study was the first to assess the impacts on feeding behaviour and activity of different sources of beef calves, and the impact of commingling at different ratios on these behaviours during the first week after arrival at the feedlot. Overall, PC calves had an increase in time spent eating compared to RS and AD calves. This evidence suggests that preconditioning calves at the ranch could positively impact feeding behaviour in the first week after arrival at the feedlot. Further, when comparing pens commingled with PC and AD calves, overall, pens with a higher proportion of PC calves had increased time spent eating compared to the pen with the lowest proportion of PC calves. Understanding the feeding behaviour and activity of PC calves and when commingled with other sources of calves provides insight into how preconditioning could improve the health and performance of calves at the feedlot, and this could allow for more investment to use preconditioning practices at the ranch. Further research into behavioural components such as social structure, social facilitation, and nutritional components like ruminal adaptation and feed intake, when commingling calves from different sources (PC, AD, RS) is needed to better understand how preconditioning can be used to develop management strategies that allow for more incentives to incorporate more PC calves at the feedlot.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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