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Original Article

Changes across time post-feed offer in the composition of total mixed ration for finishing beef cattle

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ABSTRACT

Cattle can select feed ingredients based on the physiological need and composition of ration provided. However, there is a paucity of knowledge regarding impact of selective feeding behavior of finishing beef cattle on the overall composition of the provided ration across hour of day during full feed period in the feedlot. Our objectives were to determine the impact of time post-feeding, location within the feed bunk, and their interaction on composition of the remaining feed. For this experiment, feed samples were collected during early- (days 3–5), mid- (days 41 and 42), and end- (days 71 and 72) feed periods from feed bunk of a commercial feedlot pen of 100 cattle gradually adapted to a high grain total mixed ration through transitions of four different rations. Samples were collected immediately after feed delivery and at different intervals of post-feed delivery from four equally spaced locations within the feed bunk and analyzed for dry matter (DM)%, crude protein (CP)%, acid detergent fiber (ADF)%, and neutral detergent fiber (NDF)% with an aim to look into changes in the composition of remaining feed in the feedlot bunk across time and location. For all three sampling periods, DM% and NDF% of feed differed significantly ($P < 0.001$) with an overall tendency to increase in DM% and a decrease in NDF% during early hours post-feeding, indicating selection of succulent and high-fiber feed. Early feed CP% differed significantly ($P = 0.023$) overtime but differences were non-significant for mid-feed ($P = 0.400$) and end-feed ($P = 0.059$) periods. Changes in ADF% were non-significant ($P = 0.074$) for early-feed period but were significant ($P < 0.001$) for mid- and end-feed periods. Locations within the feed bunk had no significant effect on composition of feed. Interactions between time post-feeding and locations were found significant ($P = 0.011$) only for end-feed NDF%. Overall these results suggest feedlot cattle select feed primarily for fiber and that affect composition of feed overtime. Given the differences in individual eating time and duration, multiple delivery of feed across 24 h and increasing feeding space can minimize the impact of selective feeding related altered composition of feed offered.

Keywords: Feed composition, feed sorting, feedlot cattle, neutral detergent fiber

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INTRODUCTION

Cattle have their inborn ability to select feed of their choice. Feedlot cattle are fed with grain-based total mixed ration (TMR) for a target body weight within a stipulated period. In general, they go through rapid adaptation to high concentrate diet; though the individual's adaptability varies considerably.[1] Feed choice and feed intake of cattle depend much on animal physiology, nutrient requirement, rumen health,[2] and composition and physical form of the feed.[3,4] Selective feeding of cattle considerably affects the composition of remaining diet.[5,6]

Feed bunk space allocation to feedlot cattle is usually lower than the required space for all cattle to feed simultaneously[7] that lead to competition for bunk space as it is reported in other group fed animals.[8] Dominant individuals will get first access to freshly delivered feed and will have the opportunity to sort the feeds of choice but less dominant individuals will have the remaining feed which may be different from the supplied formulation. Less dominant individuals may also be replaced from their preferred location of feed bunk. As a result, the health and performance of the less dominant individuals may be affected. Hence, it is important to understand how feed composition changes overtime after feed delivery throughout the day. The present study is undertaken keeping in view the

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hypothesis that feed composition in the feedlot bunk varies across time and location within the feed bunk, and time and location may significantly interact the composition of the feed offered.

MATERIALS AND METHODS

For this study, animal observation and feed sample collection were performed at a commercial beef fattening farm during the period of March 24–June 1, 2018, and the laboratory analyses of the feed samples were done by July 2018. All the experimental protocols were designed with no invasive procedures to conform minimal disturbances to cattle while collecting feed samples.

The Experimental Pen and Animals

A feedlot pen of 100 crossbred cattle (mix of different *Bos taurus* and *Bos indicus* breeds, of different sex, coat color and type, and of similar age group) was used for this study. The pen was approximately 985 m^2, feed bunk space was 21 m lengthwise, and there was one water trough at the back of the pen.

Feed and Feeding Schedule

Four different TMRs were used to make the animals gradually adapted to high grain TMR within 2 weeks. Ration 1 (low in grain, 36%) was used only for the very 1st day of their entry into feedlot, they were shifted to ration 2 (medium in grain, 43%) and ration 3 (high in grain, 54%) for 5 consecutive days on each ration, respectively, and a transition to ration 4 (very high in grain, 63%) was implemented providing 60% of the total allocation from ration 3 in the morning and 40% from ration 4 in the afternoon for next 4 days; provided that ration 1 to ration 3 was allocated only once in the morning of the designated days. From day 16 to rest of the trial period, ration 4 was allocated 3 times (20% early morning, 20% morning, and 60% early afternoon hours) a day. Detail of the rations allocated to the animal and chemical composition of the main ingredients is given in Table 1. Wheat was the main grain source in ration 1, 2, and 3 but barley substituted wheat in the ration 4.

Feed Sample Collection and Preservation

Feed samples were collected during the early-feed period (days 3-6), mid-feed period (days 41 and 42), and end of feed period (days 71 and 72). Ration 2 was in use during early-feed sample collection and ration 4 for the mid- and end-periods. Four locations were marked in the feed bunk at equal intervals lengthwise to collect handful (approximately 100 g) of samples from each location. Sampling was done immediately after the delivery of fresh feed and at hourly intervals up to 7 h post-feeding. Every delivery of fresh feed within the same ration category was recorded as a different feed allocation. Polyethylene sample bags were used to keep the samples air tight and stored in a insulated cooler bag (ice bag) to keep them cool for day long observation. Each sample bag was marked with ration type, date, time, and location of sampling for proper identification. After finishing each day's observation, collected samples were refrigerated at –20°C and at the end of each day session, samples were transferred

Table 1: Rations allocated to the experimental pen throughout the full feeding period

Items	Level of inclusion (% of ration)			
	Ration 1	Ration 2	Ration 3	Ration 4
Ingredients				
Oaten hay	3.50	3.00	2.00	-
Cotton hulls	12.50	10.00	8.50	3.00
Barley silage	29.00	25.00	15.00	-
Sorghum silage	-	-	-	12.00
Whole cotton seed	13.00	13.00	13.00	13.00
Wheat	36.60	43.00	54.70	-
Barley	-	-	-	63.80
Oil	1.00	1.50	2.00	3.20
Liquid finisher supplement	4.40	4.50	4.80	5.00
Total	100	100	100	100
Composition*				
DM%	68.09	69.74	73.63	74.23
CP% (DM basis)	13.13	13.25	13.40	14.14
NDF% (DM basis)	38.28	34.07	29.00	27.38
ME (MJ/kg DM)	11.34	11.82	12.61	14.05

*DM: Dry matter, CP: Crude protein, NDF: Neutral detergent fiber, ME: Metabolizable energy to the laboratory in an insulated cooler bag within 6–8 h and refrigerated at –20°C until analysis.

Feed Analysis

Feed samples were analyzed for dry matter (DM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) contents. Fresh samples were kept at 55°C for 48 h and were ground by a hammer mill with 1 mm sieve (Thomas-Wiley Laboratory Mill Model 4, Thomas Scientific, NJ, USA). Fresh sample DM and DM for laboratory purpose were determined as per the method 1.3 R of Australian Fodder Industry Association (AFIA) (2011).[9] Samples were analyzed for nitrogen (N) using a Leco FP-628 analyzer (Leco Corp., St. Joseph, MO, USA) with CP concentration calculated as N × 6.25. NDF and ADF were determined using the method 1.8 A(a) and 1.9 A(a), respectively, of AFIA (2011).[9] In total, we have analyzed 72 samples for early feed period and 36 samples for each of the mid- and end-feed periods.

Statistical Analysis

The locations within the feed bunk with the allocated TMR were considered as the experimental unit. Feed samples were collected from four locations of the bunk, at different time intervals post-feeding and for different feed allocations within and between sampling days. We have recorded, organized, and calculated averages and percentages of the feed analysis data using Microsoft Excel program. As we have collected feed samples during early, mid, and end of feed periods, and we had ration 2 for early-feed period and ration 4 for both mid- and end-feed periods, we analyzed the data restricting them to each ration category and respective sampling period using statistical package of GenStat (GenStat for Windows, 18th Edition, VSN International 2016, Hemel Hempstead, UK). We have tested the fixed effect of time post-feeding, location, the interaction of time post-feeding × location on DM, CP, ADF, and NDF percent of feed, putting sample number as random term in the mixed models (REML – linear mixed models) in GenStat. Statistical significance was determined at $P < 0.05$. A statistical tendency was determined at $0.1 > P > 0.05$.

RESULTS

Time post-feed delivery had significant effect on composition of remaining feed in the feedlot bunk [Figure 1]. The DM% gradually increased from 65.38 to 70.42 (average SED 1.303, $n = 72$) up to 6–7 h post-feed delivery and then it went down to 67.92 at 7–8 h for early-feed period ($P < 0.001$). The DM% increased from 71.07 to 77.21 (average SED 1.119, $n = 36$) and from 70.07 to 75.05 (average SED 1.125, $n = 36$), respectively, for mid- and end-feed periods ($P < 0.001$) for observations up to 2–3 h post-feed delivery. Variation overtime in CP% was

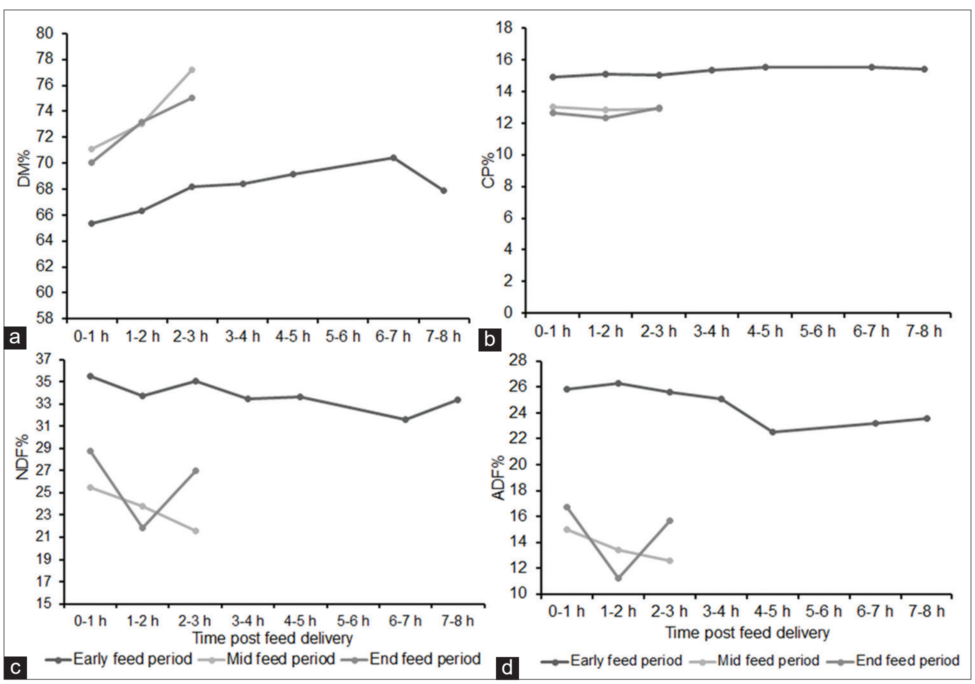

Figure 1: Changes overtime in (a) dry matter (DM), (b) crude protein (CP), (c) acid detergent fiber, and (d) neutral detergent fiber (NDF) content of remaining feed in the feedlot feed bunk. Feed was delivered once a day in the morning for early-feed period (days 3–6) and samples were collected up to 7–8 h post-feed delivery. During mid- (days 41 and 42) and end- (days 71 and 72) feed periods, feed delivery was thrice a day and it was possible to collect samples up to only 2–3 h post-feed delivery. Ration 2 (DM 69.74%, CP 13.25%, NDF 34.07% and metabolisable energy [ME] 11.82 MJ/kg DM) was supplied during early-feed period and ration 4 (DM 74.23%, CP 14.14%, NDF 27.38% and ME 14.05 MJ/kg DM) for mid- and end-feed periods of sample collection

significant ($P = 0.023$) for the early-feed period and there was non-significant variation during the mid- ($P = 0.400$) and end- ($P = 0.059$) feed periods. Feed NDF% significantly ($P < 0.001$) changed overtime for all the three sampling periods. Time post-feeding had non-significant effect on early-feed ADF% but it showed a statistical tendency ($P = 0.074$) to reduce overtime. Changes in ADF% of mid- and end-feed periods were significant ($P < 0.001$).

Locations within the feed bunk had no significant ($P > 0.1$) effect on the composition of remaining feed throughout the observation periods. Interactions between time post-feeding and location of the feed bunk [Figures 2-4] also had no significant ($P > 0.08$) effect on feed composition for all the cases except for end-feed period NDF% (significant at $P = 0.011$).

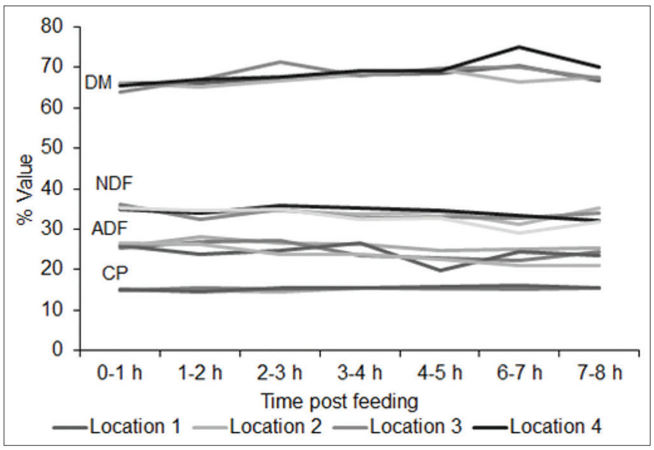

Figure 2: Feedlot feed composition as affected by time post-feeding and location within the feed bunk interactions during early-feed period (days 3–6 on feed)

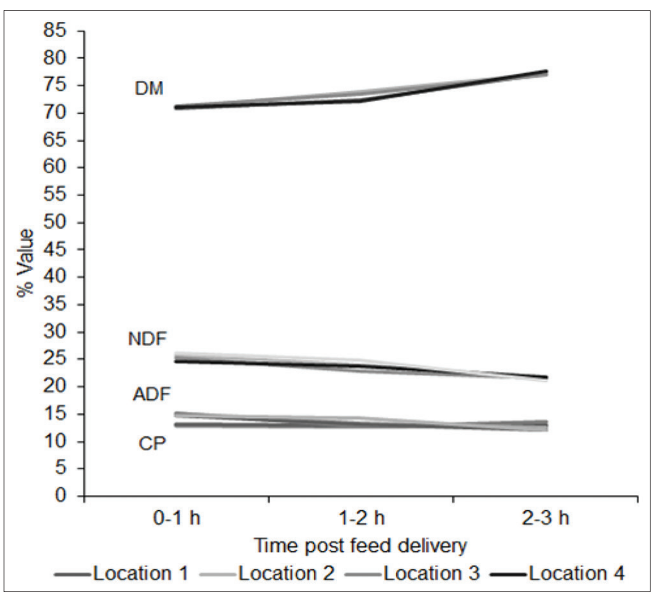

Figure 3: Feedlot feed composition as affected by time post-feeding and location within the feed bunk interactions during mid-feed period (days 41 and 42 on feed)

DISCUSSION

A change overtime in the composition of remaining feed in feedlot bunk is due to selective feeding of feedlot cattle. Increase in DM% [Figure 1] of remaining feed in the feedlot bunk indicates cattle sorted succulent feed particles from TMR. Considering the ingredients of rations [Table 1] provided to the cattle, it is only possible by selecting silage particles against other ingredients. Sugarcane silage allowed cattle to ingest higher amount of NDF compared to whole crop maize silage,[10] indicating cattle's preference for silage. During the early-feed period, ration 2 was allocated only once a day (early morning) and silage inclusion level was 29% of total ration, which may have allowed cattle to select for silage up to 6–7 h post-feed delivery and resulted in gradual increase in DM% in the remaining feed. To a lesser extent, increase in DM% can be attributed to evaporative losses of moisture due to sunlight. The decrease in DM% during 7–8 h can be explained by the fact that there was not much silage remaining at that time to select for and cattle might had changed their selection strategy in the afternoon hours and also cooler afternoon hours might allowed some air moisture be absorbed by feed particles. During mid- and end-feed periods, ration 4 (12% silage) was allocated in three instalments (early morning 20%, late morning 20%, and early afternoon 60% at around 3 h intervals) that allowed cattle to go for more selective feeding for silage and resulted the continuous increase in DM% in the remaining feed up to 2–3 h of observation post-feed delivery.

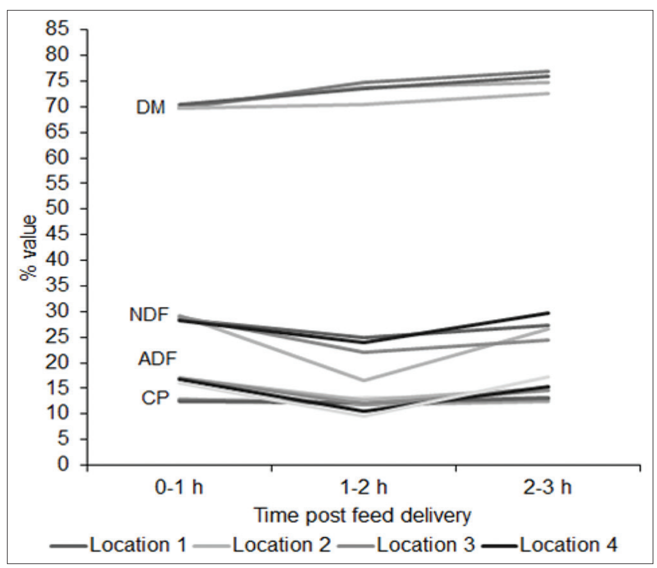

Figure 4: Feedlot feed composition as affected by time post-feeding and location within the feed bunk interactions during end-feed period (days 71 and 72 on feed)

Increase in CP% [Figure 1] in the remaining feed during early-feed period suggests that cattle had selected feed against whole cotton seed and wheat since they were the protein-rich ingredients in the ration of that period. Selection for cotton hulls (lowest protein among all selectable ingredients) may also contribute to increase in CP% in the remaining diet. However, it can only be speculated from the changes in chemical composition as we did not analyze the proportionate ingredient percentage of remaining feed. However, inclusion of cotton seed hull resulted increased fiber intake[11] that supports our speculation. Cotton hulls and silage inclusion level were reduced and wheat was supplemented by increased level of barley during mid-feed and end-feed periods. Non-significant changes in CP% in these periods indicate that there was less chance for cattle to select feed for or against CP content and they were adapted to high grain ration. Similar finding has been reported from Roman *et al*. (2011),[10] they found non-significant differences in CP intake by finishing feedlot cattle in an experiment with different diet formulations.

Feedlot cattle primarily selected feed for fiber as indicated by sharp decreases in NDF% [Figure 1] of remaining feed sampled within 1–2 h post-feed delivery during all three observation periods. Although the early-feed NDF% fluctuated much, the decreasing trend was maintained all the way for early- and mid-feed periods. End-feed NDF% at 2–3 h was higher than the previous observation; it indicates that during that period cattle selected more grain. ADF% of the remaining feed during early-feed period also showed overall decreasing trend though the differences were non-significant statistically. Mid-feed ADF% showed continued decreasing trend, whereas end-feed ADF% decreased at 1–2 h and increased at 2–3 h post-feed delivery. This findings support that cattle selected feed for fiber in the early hours post-feeding, and in the later hours, less fiber was remaining that made them to eat more concentrates. Kononoff and Henrichs (2003)[11] reported increased NDF intake with decreasing forage particle length and inclusion of cotton seed hull. Cozzi and Gottardo (2005)[5] found a decrease in NDF of feed samples when selection was toward longer particles. Crossley *et al*. (2017)[12] found that cows sort long particles under low competition but they sort against long particles under high competition. Custodio *et al*. (2016)[2] linked rumen health to preferential consumption for long and medium particles by beef cattle. All these studies are in alignment with our results. DeVries *et al*. (2005)[6] considered changes in NDF content of TMR throughout the day to determine the extent of feed sorting and found that NDF content increased throughout the day. Similarly, sorting of feed for grain or small particles has been reported in some previous studies[3,13,14] which contradicts our present finding but those studies were mostly done with dairy cattle. Therefore, dairy and beef cattle sort feed differently based on composition of the available ration and physiological demand.

Our supposition that cattle eating from different places within the feed bunk may receive different diets was not accepted. Our results clearly represent that there was non-significant differences among locations for DM%, CP%, ADF%, and NDF% during all three periods of sample collection. This is a good indication that TMR provided was homogenously mixed and cattle eat out equally from all locations. However, feed composition may vary among locations within the feed bunk if TMR is improperly mixed and if amount of feed supplied varies among locations.

Interactions between time post-feeding and locations within feed bunk for early-, mid-, and end-feed periods, as presented in Figures 2-4, respectively, showed only significance for NDF% during end-feed period. These results can be interpreted that cattle had no significant choice of feeding from a particular location at a specific time point. Effect on end-feed NDF% is the result of abrupt reduction in NDF at the combination of 1–2 h post-feeding and location 2. Cattle might have selected more NDF containing ingredients (cotton hulls and sorghum silage) at this specific time and location combination.

Feedlot cattle sorted feeds primarily for fiber as indicated by the laboratory analyses of feed samples collected at the time of delivery and at different intervals. The usual linear bunk space provided to feedlot cattle does not allow all cattle to eat at a time when freshly mixed feed is delivered; only the dominant cattle can get first access and the subordinate cattle get delayed access to feed bunk and thereby the lower ranking groups may have a different feed than the supplied formulation. Less fiber in the remaining ration may affect health and performance of less dominant animals. During the early-feed period, cattle experienced heat stress (data are not shown) that might have shaped their feed sorting behavior based on physiological and metabolic needs, especially the rumen health. In this study, number of samples, ration type, and allocation varied throughout the observation periods. We have not followed the changes over 24 h. Some abrupt changes may not be generalized as sample size was not large enough. Further study with specific ration for 24 h observation may give better insight into this line.

CONCLUSION

Composition of allocated ration to feedlot cattle changes overtime due to selective feeding as indicated by chemical analysis of remaining feed in the feed bunk at different intervals post-feed delivery. Overall decreasing trend in NDF content during the 1st few hours post-feed delivery indicates sorting of feed primarily for fiber. Due to limited feed bunk space allocation for feedlot cattle, dominant individuals may sort out feed of their choice and leave the ration with changed composition for less dominant cattle. In this way, less dominant individual may not have required fiber in their diet to maintain rumen health and overall feedlot performance may be affected.

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