Physically effective fiber changes nutrient levels of total mixed ration and fecal parameters in beef feedlots

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ABSTRACT: This study evaluated the effects of the physically effective fiber (peNDF) content on nutrient composition of the total mixed ration (TMR), orts and fecal parameters in 15 commercial beef feedlots. The particle size distribution of TMR was measured adopting Penn State Particle Size Separator (PSPS). Samples were evaluated for dry matter (DM), ash, ether extract (EE), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and starch content. Fecal samples were also evaluated for pH and score. The feedlots were categorized into peNDF<20% and peNDF ≥ 20%. Data were analyzed by a model that included fixed effects of treatment and covariates (sex and genetic groups). Levels of DM, CP, EE and starch were lower in TMR with peNDF ≥ 20% (P<0.05). Fecal dry matter was higher and morning fecal pH was lower for TMR with peNDF<20% (P<0.05). Physically effective fiber changed nutrient levels in TMR, orts, fecal pH and DM. So, using PSPS and fecal parameters are practical and indirect tools for measuring fecal starch and assessing the effectiveness of the diet supplied to ruminants.

Key words: particle size distribution, starch, fiber effectiveness.

INTRODUCTION

The challenge of today’s beef cattle feedlot systems using high-concentrate diets is to balance the levels of readily fermentable carbohydrates with physically effective fiber (peNDF), which is important to reduce the risk of disorders and maintain a healthy rumen environment. The peNDF is the fraction of the fiber that stimulates chewing activity and maintains a healthy rumen environment by combining the chemical and physical properties of feeds (MERTENS, 1997). Consequently, increasing fiber effectiveness can help increase rumen pH by stimulating the production of saliva and chewing activity. Moreover, fiber creates a more suitable rumen environment for the degradation of nonstructural carbohydrates and maintains an adequate balance in short-chain fatty acid production (ALLEN, 1997; STONE, 2004).

The Penn State Particle Separator (PSPS) is the main method for measuring particle size distribution of total mixed ration (TMR) and silages. The original model of PSPS consisted of two screens with circular holes sized 19 mm (Upper) and 8 mm
Samples of TMR were collected in three points of the new PSPS (19, 8 and 4 mm) (HEINRICHS, 2014). Samples of TMR were immediately sieved on the farm to determine their particle size by using the new PSPS (19, 8 and 4 mm) (HEINRICHS, 2014). Samples of TMR were collected in three points of the bunk feed (beginning, middle and end) and the average particle size of each farm was calculated. The peNDF concentration was calculated using two methodologies: 1) peNDF - percentage of particle fraction retained (greater than 4 mm) multiplying by the percentage of NDF in TMR sample (HEINRICHS, 2014); 2) peNDFa- percentage of particle fraction retained (greater than 4 mm) multiplying by the percentage of NDF from each screen after sieving [Adapted of HEINRICHS (2014)]. These method assumptions, in which fiber fraction when sieved contain varying levels of NDF and that partially explains the many contradictions in the literature about effects of peNDF on animal performance.

The farms were divided into two groups: peNDF<20% (8 feedlots) and peNDF ≥ 20% (7 feedlots). The groups were divided based on a threshold value of 20% peNDF content because farmers of the study region use high levels of roughage in feedlot TMR and, furthermore, following recommendations to optimize forage degradation (NRC, 2016; FOX & TEDESCHI, 2002).

After collecting TMR and art samples, fecal disorders were evaluated, both in the morning and afternoon, from three animals at each bunk feed where was collected TMR and orts. Fecal score (FS) was determined by visual assessment according to IRELAND-PERRY & STALLINGS (1993). Fecal samples were saved straight from the floor after FS assessment, taking a sample from the top of the pile to avoid soil contamination. Fecal pH was determined immediately after sampling mixing 100 ml of distilled water and 15 g of fresh feces in a glass flask using a portable thermometer and a pH meter (AK 103®). Starch was determined using the method described by HALL (2008).

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**MATERIALS AND METHODS**

Fifteen commercial beef feedlots were visited just once and information on the genetic group (Nellore, Angus x Nellore, and animals crossed with other Zebu breeds or from dairy crosses) animal category (female, male, castrated or intact) was collected from 2 to 4 random pens in each feedlot. The samples of TMR and orts from each farm were taken, directly from the mixer and bank, just before the TMR distribution at the beginning. Samples were collected in the middle of the feedlot period, after adaptation to TMR. The TMR consisted of different sources of roughage (grass, sugar cane, corn and sorghum silages) and concentrate (differently processed corn kernels, soybean hulls, sorghum and citrus pulp). The farms were divided into two groups: peNDF<20% (8 feedlots) and peNDF ≥ 20% (7 feedlots). The groups were divided based on a threshold value of 20% peNDF content because farmers of the study region use high levels of roughage in feedlot TMR and, furthermore, following recommendations to optimize forage degradation (NRC, 2016; FOX & TEDESCHI, 2002).

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was used for the chemical composition of TMR orts and feces. The model included feedlot as a random effect, sex as a fixed effect and genetic group as covariates: \( y_{ijk} = \mu + G_i + S_j + T_k + e_{ijk} \); where: \( \mu \) = overall mean; \( G_i \) = effect of the genetic group; \( S_j \) = effect of sex; \( T_k \) = effect of the group; \( e_{ijk} \) = residual error, assumed to be independently and identically distributed in a normal distribution with mean zero and variance \( \sigma^2 \). Data were analyzed using PROC MIXED (SAS, 2004) and mean separation was calculated running the LSMEANS test at \( P \leq 0.05 \). The effects were considered significant at 5%.

Concordance Correlation Coefficient (CCC) according LAWRENCE & LIN (1989), was performed using the PROC IML (SAS, 2004) for evaluating agreement between the methods of peNDF estimation. Lin’s CCC is the concordance between a new test or measurement (Y) and a gold standard test or measurement (X). This statistic quantifies the agreement between these two measures of the same variable. The CCC was considered low for values <0.40, moderate >0.40, and <0.75, excellent > 0.75 and confidence interval (CI) of 95% were used.

RESULTS AND DISCUSSION

Diets with peNDF ≥ 20% had a higher number of particles retained on the 19, 8, and 4-mm sieves (\( P < 0.05 \)), higher number of particles larger than 4 mm (\( P < 0.0001 \)) and a lower amount of particles smaller than 4 mm (\( P < 0.0001 \)), compared to diets with peNDF<20% (Table 1). Despite the difference, the upper fraction (19 mm) of TMR for both treatments were within the guidelines reported by HEINRICHS (2014). Nevertheless, the middle and lower screen fraction (8 and 4 mm) of TMR for both treatments were lowest and highest the guidelines reported by HEINRICHS (2014), which suggested a mean incidence of middle fraction ranging from 30 to 50% and 10 to 20%, respectively. In particular, the highest percentage of particles collected in the bottom pan (< 4 mm) for diets with peNDF<20% probably

| Item                  | peNDF<20% | peNDF≥20% | SEM     | P-value |
|-----------------------|-----------|-----------|---------|---------|
| **Particle Separator of TMR, %** |           |           |         |         |
| 19 mm                 | 2.53      | 5.04      | 1.136   | 0.0336  |
| 8 mm                  | 12.61     | 21.98     | 2.595   | 0.0008  |
| 4 mm                  | 25.54     | 34.86     | 1.893   | <0.0001 |
| Particles > 4mm, %    | 39.49     | 62.18     | 2.528   | <0.0001 |
| Particles < 4mm, %    | 60.50     | 37.81     | 2.528   | <0.0001 |
| peNDF, %              | 16.28     | 26.07     | 1.015   | <0.0001 |
| peNDFa, %             | 18.35     | 28.00     | 1.275   | <0.0001 |
| **Nutrient composition of TMR, %** |           |           |         |         |
| Dry matter            | 54.08     | 43.43     | 1.924   | <0.0001 |
| Crude protein         | 14.86     | 11.61     | 0.552   | <0.0001 |
| Ether extract         | 6.62      | 4.45      | 0.539   | 0.0002  |
| Neutral detergent fiber| 40.01    | 43.15     | 1.791   | 0.0868  |
| Acid detergent fiber  | 21.88     | 23.59     | 1.159   | 0.1489  |
| Starch                | 33.32     | 27.20     | 2.265   | 0.0100  |
| **Nutrient composition of orts, %** |           |           |         |         |
| Dry matter            | 69.88     | 53.55     | 2.445   | <0.0001 |
| Crude protein         | 14.13     | 11.58     | 0.427   | <0.0001 |
| Ether extract         | 5.99      | 5.83      | 0.487   | 0.7483  |
| Neutral detergent fiber| 26.87    | 38.07     | 2.849   | 0.0003  |
| Acid detergent fiber  | 12.80     | 20.55     | 1.858   | 0.0002  |
| Starch                | 30.39     | 33.03     | 2.938   | <0.0001 |

1Physically effective fiber: percentage of particle fraction retained (greater than 4 mm) multiplying by the percentage of NDF in TMR sample (HEINRICHS, 2014).

2Physically effective fiber: percentage of particle fraction retained (greater than 4 mm) multiplying by the percentage of NDF from each screen after sieving [Adapted from HEINRICHS (2014)].
occurred because many processed grains, byproducts, and pelleted grains have accumulated below.

The concentration of peNDF and peNDFa was higher for diets with peNDF ≥ 20% (P<0.0001). This suggests that the physical effectiveness of TMR was not similar despite the same inclusion of NDF. Therefore, the particle size of the diet is the most influential factor affecting physical effectiveness, and NDF is not a useful parameter to evaluate the fiber in feedlot diets (MERTENS, 1997).

The CCC analyses between the two methodologies were considered moderate [CCC = 0.75; CI 95% (0.44-0.90)]. Despite the moderate correlation between the two methods and the greater accuracy of the method by peNDFa, using peNDF in ration balancing, even using a single NDF value, is less expensive and more practical for daily field operations (ZEBELI et al., 2012; HEINRICHS, 2014). However, farmers using the peNDF in TMR containing whole grains and pelleted supplements should be careful because these ingredients can be retained on the 4-mm sieve. Thus, they will increase the peNDF content, even though they are rapidly fermented ingredients (HEINRICHS, 2014). NATIONAL ACADEMIES OF SCIENCES and MEDICINE (2016) suggests to overcome this limitation calculating the peNDF of forages in TMR, ignoring the peNDF of processed ingredients.

The levels of DM, CP, EE and starch were higher for diets with peNDF<20% (P<0.05); although, the NDF and ADF contents were similar between treatments (P>0.05) (Table 1). The higher concentration of nutrients in TMR with low fiber effectiveness can be attributed to the low inclusion of roughage in the diet. Feeding high levels of roughage to finishing cattle dilutes dietary energy and nutrient availability depending on the roughage quality. In this study, similar contents of NDF and ADF can be attributed to the substitution of roughage with a co-product or high-fiber roughage in farms feeding TMR with peNDF<20%. In some farms that fed a high concentrate: roughage ratio, co-products such as soybean hulls and roughage with high NDF content, such as grass and sugarcane silages, were also used.

The levels of DM, CP and starch in orts were higher for diets with peNDF<20% (P<0.05), as well as their levels in TMR (Table 1). Although, there were no differences between treatments in NDF and ADF concentrations in TMR, their levels in the orts were higher for diets with peNDF ≥ 20% (P<0.001) (Table 1). This demonstrates that animals fed with TMR with higher levels of physically effective fiber were selective and possibly refused the long particles.

Fecal score was not influenced by the fiber effectiveness of diets (P>0.05), as well as the fecal output of NDF, ADF, CP, EE and starch (P>0.05) (Table 2). Fecal score variables were probably similar because TMR samples and fecal score were taken on the same day. There is a correlation between particle size and fecal score two days after the intake of TMR (MELENDEZ & ROY, 2016). The authors observed that almost 20% of the variability in fecal score was explained by the distribution of the particle size of TMR fed 48 h earlier. Furthermore, they reported that the fecal score increased with increasing percentage of particles retained on the 19-mm sieve, over 15% of the total DM. In this study, the maximum percentage of particles retained on the 19-mm sieve was 5%, which shows that the low levels of long particles in the TMR were not enough to modify the fecal consistency. Alternatively, the study by SILVA et al. (2012) on the use of whole corn grain-based diets and two types of roughage in feedlot showed that animals fed TMR with the lowest level of peNDF had a lower fecal score (2.92).

Despite no difference in fecal starch excretion had been observed, fecal morning pH was lower for animals fed diets with peNDF ≤ 20% (P<0.05) (Table 2). It is probably because the difference in TMR starch content. However, microbial fermentation can occur in the large intestine, producing lactic acid and short-chain fatty acids, consequently decreasing fecal pH (CHANNON et al., 2004; SILVA et al., 2012)

However, fecal DM was lower for animals fed diets with peNDF ≥ 20% (P<0.05) (Table 2). Fecal DM was lower, probably because TMR with high fiber effectiveness may have increased the chewing activity and had a positive effect on ruminal function, which resulted in high DM digestibility in the total tract. Thereby, fecal parameters can be practical and indirect tool for measuring fecal starch in commercial beef feedlots.

These results are in agreement with some reports (BEAUCHEMIN & YANG, 2005) but in discord to other researchers (HALES et al., 2014; WEISS et al., 2017). BEAUCHEMIN and YANG (2005) observed that the clear total tract digestibility of DM increased linearly with increasing peNDF in diets for lactating cows, whereas WEISS et al. (2017) observed that decreasing DM digestibility can be effect of increasing forage in feedlot diets. These discrepancies between studies are probably related to differences in the concentration of dietary

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**CONCLUSION**

Diets with more than 20% peNDF have a larger particle size, lower nutrient content and lower concentration of dietary starch; and consequently, less fecal DM. So, physically effective fiber changed nutrient levels in TMR, orts, fecal pH and dry matter. Using PSPS and fecal parameters can be practical and indirect tools for measuring fecal starch and effectiveness of feeding in commercial beef feedlots.

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**DECLARATION OF CONFLICT OF INTERESTS**

The authors declare that there are no conflicts of interest. The financial support had no influence or role in the experimental design, data analysis, writing of the paper, or the decision to publish this paper.

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