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Effect of compound feed pelleting and die diameter on rumen fermentation in beef cattle fed high concentrate diets

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ABSTRACT

The effect of feeding a compound feed as meal (M) or pelleted at 3.5 (P3.5) or 10 (P10) mm i.d. on feed intake pattern and rumen fermentation in growing calves was investigated. Compound feeds were fed *ad libitum* with barley straw to six 3-mo-old rumen cannulated calves in a double 3 × 3 Latin square arrangement. In a first 9-wk phase (I) free access to concentrate was allowed, whereas in a second 6-wk phase (II) access was restricted to 09:00 h to 11:30 h and 17:00 h to 19:30 h. Rumen samples were collected on two non-consecutive days at 08:30 h, 13:00 h and 17:00 h. Pelleting increased the degree of starch gelatinization from 0.113 in M to 0.205 and 0.154, in P3.5 and P10. In both phases, P10 slowed consumption of concentrate during morning feeding (P<0.01), although treatments did not affect total daily concentrate intake (97 g DM/kg $LW^{0.75}$ and 82 g DM/kg $LW^{0.75}$) in phases I and II. In phase I, pH before morning distribution was lower than in phase II (6.5 *versus* 7.2). Four hours after feeding, there was a pH drop (P<0.001), which was higher in phase II (1.5 units) than in phase I (0.7 units), in line with a higher concentrate intake (4.10 kg *versus* 1.89 kg). Calves fed P3.5 tended (P=0.052) to a lower pH than those on M in phase I, and those fed P10 had the least decrease in pH after feeding. No pH differences occurred between treatments in phase II, although pH recovery from 4 to 8 h after feeding tended to be more (P=0.073) for P10. Rumen lactic acid concentration increased after feeding (P<0.05 and P<0.001) in phases I and II, reaching 45.7 mg/l and 39.6 mg/l, respectively. In phase II, P3.5 animals reached a higher (P<0.01) concentration than M and P10 animals. Rumen ammonia concentration decreased (P<0.001) after feeding, reaching the lowest values 4 h later (23.3 mg/l and 13.6 mg/l in phases I and II). P3.5 showed lower ammonia concentration than M in phase I (P<0.05). Total volatile fatty acid (VFA) concentration increased (P<0.001) after feeding in both phases, decreasing the acetic to propionic ratio (P<0.001). In phase I, calves fed M tended (P=0.074) to have lower total VFA rumen concentration and higher acetic to propionic ratio (P<0.01) than those fed pellets. Results suggest that with pelleting at 3.5 mm, increased ruminal fermentation rate dominates regulation of substrate delivery and results in lower pH values that could eventually translate into higher risk of acidosis compared with unprocessed meal. Increasing the pellet diameter to 10 mm may decrease the rate of fermentation through a homogeneous daily intake pattern, without affecting total intake, even under conditions of restricted feeding.

Abbreviations: aNDFom, neutral detergent fibre assayed with a heat-stable amylase and expressed exclusive of residual ash; CP, crude protein; DM, dry matter; EE, ether extract; LW, live weight; OM, organic matter; M, meal; P3.5, pelleted with a 3.5 mm die diameter; P10, pelleted with a 10.0 mm die diameter; VFA, volatile fatty acids.

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1. Introduction

Widespread use of high cereal diets in intensive beef production systems in Southern Europe, where animals are fed compound feeds *ad libitum* with straw, may result in low ruminal pH and risk of ruminal acidosis (Owens et al., 1998; Sauvant et al., 1999; Nagaraja and Titgemeyer, 2007). Antimicrobial compounds, mainly ionophores such as monensin, have been successfully used to improve efficiency of nutrient utilization and reduce the risk of ruminal acidosis and bloat (Bergen and Bates, 1984; Nagaraja, 1995). However, use of antibiotics in animal feeds has been banned in the European Union since January 2006. Alternatives to antibiotic additives include organic acids, probiotics, plant extracts, buffers (Martin, 1998; Calsamiglia et al., 2012) in addition to improved feedstuff characterization, feed formulation, physical form of feed presentation and feeding management, in an attempt to reduce acidosis risks without compromising production efficiency.

Feed processing generally increases starch gelatinization and its extent and rate of ruminal fermentation (Theurer, 1986; Huntington, 1997; Solanas et al., 2005) which, in general, positively affects feed utilization (Theurer, 1986; Owens et al., 1997; Beauchemin et al., 2001). However, increased fermentability may also lead to a lower ruminal pH (Sauvant et al., 1999) and consequently a higher risk of acidosis. We are not aware of any *in vivo* study on effects of concentrate pelleting and pellet size on ruminal fermentation. However, Castillo et al. (2006) showed a more stable blood acid–base balance over time in feedlot steers fed a pelleted feed compared to those fed meal, although higher levels of L-lactate and lower base excess (BE) and HCO^{-3} values reflected a higher risk of acid overload in cattle fed pelleted grain.

Grinding is mechanical breakdown of grains with no changes in chemical structure, whereas pelleting incurs disruption of the starch/protein matrix, some degree of starch gelatinization, and reduction of particle size, which facilitates microbial and enzymatic access to the starch granules and increases rate of fermentation (Bertipaglia et al., 2010). In contrast, pelleting may prolong the time needed to disintegrate the pellet, delaying the accessibility of micro-organisms to potentially fermentable organic matter (OM). This could be of relevance in ruminants fed high concentrate diets with very low forage and fibre content, and the resultant lower chewing and rumination activity (Allen, 1997). These factors may counterbalance each other in the total effect of pelleting on the ruminal environment. In an in situ experiment at the Nutreco Ruminant Research Centre (Van Laar et al., 2007), 8 mm pellets were fermented at a slower rate than 3.5 mm pellets. Bertipaglia et al. (2010) found higher gas production during the first 6 h of incubation of a complete diet (0.9:0.1, concentrate:straw as fed) when it was fed as meal than when it was pelleted with a 10 mm diameter die, and recorded intermediate values when the concentrate was pelleted to a 3.5 mm size. In contrast, when the compound feeds were incubated after milling to pass a 1 mm diameter mesh, the pelleted treatments produced more gas than the meal treatment. Although in situ and *in vitro* results cannot be directly extrapolated to *in vivo*, because feed is not subjected to chewing and rumination in situ and *in vitro*, we hypothesize that pelleting can alter fermentation kinetics and/or feeding behaviour.

The aim was to study the *in vivo* effect of form of presentation of compound feed, as meal or in pellets of different diameters, on ruminal fermentation of growing beef cattle, when fed *ad libitum* in combination with straw. Experimental diets were also examined under conditions of restricted access time to the concentrate in an attempt to simulate the stress originated by social competition when feed bunk space is limited, which could be the origin of some cases of acidosis in farm conditions (González et al., 2012).

2. Materials and methods

2.1. Animals

Six 3 mo old non-specific crossbred male calves with an initial live weight (LW) of 145 ± 1.9 kg were housed indoor individually on slatted concrete floor pens fitted with automatic water dispensers and two separate feeders for concentrate and forage, with natural or artificial light for 12 h/d. Animals were cannulated in the rumen at the beginning of the experiment using 10 mm i.d. cannula (ref. 4130107, DIVASA FARMAVIC S.A., Gurb-Vic, Barcelona, Spain). Before the experiment, the calves were fed a commercial post-weaning concentrate and straw *ad libitum* for 2 wk to adapt them to the high concentrate diet and to the experimental housing conditions. Calves were randomly allocated to one of three experimental diets according to a double (3×3) Latin square arrangement. All animal care, handling and surgical procedures were approved by the Ethics Committee of the University of Zaragoza (Zaragoza, Spain).

2.2. Diets

Diets consisted of compound feed and chopped barley straw, both offered *ad libitum*. The compound feeds were formulated with the same ingredients and in the same proportions (Table 1) and were produced the same day in the same factory (Nanta S.A., Zaragoza, Spain). The feed was produced in three ways as: meal (M) or pelleted with two different die diameters (3.5 mm – P3.5 or 10.0 mm – P10). The initial particle size distribution of the meals was identical as all feeds were milled before pelleting to pass a 3 mm mesh. Manufacturing conditions for the pellets were: for P3.5, effective length, 60 mm; durability, 0.99; for P10, effective length 120 mm; durability 0.95. Steaming was applied at a pressure of 2500 kPa, and fines were discarded.