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Supplementation of sugar cane diets for Brazilian dairy cattle: a modelling study

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Introduction

Sugar cane is a readily available forage for dairy cattle in Brazil. The crop largely comprises fibre and water soluble carbohydrate and has a low nitrogen content. The search for suitable low-cost supplements is therefore of major importance to the dairy industry centred in the south-east region. In order to help eliminate unnecessary feeding trials, a mechanistic model of the rumen was constructed with the primary objective of predicting nutrient supply to the host animal from dietary intake, as a means of indicating pre-experimentally which combinations of locally available supplements are most likely to enhance sugar cane diets.

Model

Within the model, the microbial population utilizes soluble carbohydrates, derived predominantly from dietary water-soluble carbohydrates and the hydrolysis of fibre and starch, and ammonia from the hydrolysis and fermentation of dietary protein, endogenous and dietary urea. Protozoa are represented as the portion of the microbial pool which is selectively retained in the rumen and microbial-matter recycling is described by the death and lysis of this portion. The remainder of the pool, which essentially represents rumen bacteria, is subject to passage with the liquid and particulate phases. Urea recycling via the rumen wall and saliva is represented by a single flux into the rumen ammonia pool, whilst ammonia is removed from the rumen by incorporation into the microbes or absorption across the rumen wall. Volatile fatty acids (VFA), produced from microbial fermentation and absorbed across the rumen wall, are represented by a single pool for simplicity. The nutrients available for absorption from the lower tract are amino acids (from microbial and dietary protein), glucose equivalents (from microbial carbohydrate, by-pass starch and water-soluble carbohydrates), and dietary lipid. The model contains 10 state variables (pools): non-soluble dietary protein, soluble protein, ammonia, lipid, undegradable fibre, potentially degradable fibre, starch, soluble carbohydrate, VFA and microbes. The flux equations are described by mass reaction or Michaelis-Menten forms. Local data obtained from digestion trials with Holstein × zebu cattle were used to parameterize the model wherever possible.

The model was validated against two experiments conducted in the state of Minas Gerais using growing steers. One, where sugar cane was supplemented with four levels of urea (0, 5, 10 and 15 g/kg inclusion as fed), and another of factorial design with two levels of intake and two levels of urea inclusion in a diet of sugar cane supplemented with rice meal. Observed values of ruminal concentrations and duodenal flows were compared with the values predicted by steady state solutions of the model. The root mean square prediction error (RMSPE) for the ruminal concentrations of VFA was 16·8% of the mean for the observed treatments and of ammonia was 22·6%. The RMSPE for the duodenal flows of non-ammonia nitrogen was 13·9%, neutral-detergent fibre 13·3%, and organic matter 8·7%.

The model was then used to investigate the effect of increased urea inclusion when a fixed level of sugar cane was offered to Holstein × zebu dairy cows. The production of microbes in the rumen increased with urea inclusion until the supply of soluble carbohydrates became limiting and remained at this level for all higher inclusions. The converse was true for ammonia concentration; it remained constant and low when soluble carbohydrates were in excess and increased with urea inclusion when they were limiting. The model was also used to examine the effect of supplementing sugar cane with rice polishings and urea by comparing six diets: low (5 kg dry matter (DM)) and high (8 kg DM) intakes of sugar cane offered alone (diets L and H); with 2 kg DM of rice polishings (diets LR and HR); and 2 kg

DM of rice polishings plus optimal urea inclusion (as defined previously by the model) for microbial growth and ammonia concentration (diets LRU and HRU). The quantity of amino acids absorbed from the lower tract on diet LR was 3·1 times that on L, and on diet HR 2·5 times that on H. The corresponding figures for absorbed glucose equivalents were 1·1 and 0·9 respectively. The VFA absorbed on LR was 1·8 of that on diet L, and on HR 1·6 of that on diet H. When optimal urea was included, absorbed amino acids on diet LRU became 4·6 times that on L, and on diet HRU 4·5 times that on H. However, owing to increased soluble carbohydrate utilization by microbes in the rumen, absorbed glucose equivalents were reduced to 0·9 of that on diet L and 0·5 of that on diet H respectively. Corresponding VFA absorption was 2·0 and 1·9 times that on diets L and H. If the intake of sugar cane on diet L is assumed to represent the *ad libitum* intake when sugar cane alone is offered and the intake on diet HRU the increased *ad libitum* intake, consistently observed, when sugar cane is supplemented with rice polishings and urea, then such supplementation increases absorbed amino acids by a factor of 6·8 and VFA by 3·1 whilst absorbed equivalents are decreased to 0·9 of that of the unsupplemented diet.

Conclusions

From the preliminary validation and application of the model outlined above, its predictions appear to be sensitive to type and level of supplementation and so the model should prove to be useful in evaluating the supplements available in Brazil for inclusion in sugar cane diets for dairy cattle.

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