Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
http://dx.doi.org/10.5424/sjar/2014124-6439

Spanish Journal of Agricultural Research 2014 12(4): 1105-1109
ISSN: 1695-971X
eISSN: 2171-9292

SHORT COMMUNICATION

OPEN ACCESS

Effect of the feed presentation form on the intake pattern, productive traits and rumen pH of beef cattle fed high concentrate diets

Antonio Gimeno, Alberto Dieste, Abdelmuhsen Al Alami, Antonio de Vega, Carlos Castrillo and Manuel Fondevila*

Instituto Universitario de Investigación en Ciencias Ambientales. Departamento de Producción Animal y Ciencia de los Alimentos. Universidad de Zaragoza. C/ Miguel Servet, 177. 50013 Zaragoza, Spain

Abstract

Nutritional disorders like ruminal acidosis are common in Spanish beef production system, in which animals are fed diets with a high content in starch. This experiment studied the effect of feed presentation form (concentrate and straw offered separately, CD, or mixed in form of briquettes, BR) on the pattern of intake, growth and rumen pH of beef cattle fed high concentrate diets. The experiment was performed with 40 Holstein male calves, 32 of them for determining feed intake pattern and productive rates, and the remaining 8, which were previously provided with a ruminal cannula, to monitor rumen pH in two 21-day consecutive periods following a change-over design. Animals fed BR reduced feed intake rate during the first hour after feeding (18.6 *vs.* 24.0% of daily intake $p < 0.001$), but this diet promoted a lower rumen pH at all sampling times compared with CD (daily average of 5.98 *vs.* 6.33; $p < 0.001$) and tended to promote a lower total feed intake (7.08 *vs.* 9.77 kg DM d^{-1}; $p < 0.001$) and daily weight gain (1.43 *vs.* 1.76 kg d^{-1}; $p = 0.056$). Offering the concentrate and the straw mixed in form of briquettes is not useful to prevent ruminal acidosis and improve growth, probably due to both a reduced particle size of straw and avoided self-regulation of straw intake along the day.

Additional key words: feed processing; high-grain feeding; rate of intake.

In Spain, beef production is mainly based on cereal-based concentrates reaching over 85% total dry matter (DM) intake plus straw, both given *ad libitum*. Under such conditions, dietary starch proportion rises up to 45% of total diet, promoting a high ruminal synthesis of volatile fatty acid and lactate, with a major risk of subacute ruminal acidosis (SARA) (Owens *et al*., 1998; Krause & Oetzel, 2006). Acidosis is the major digestive disorder in feed intensive farms (Nagaraja *et al*., 1998), affecting animal welfare and economy of beef production. Although not always associated with a drop of average performance (Schwartzkopf-Genswein *et al*., 2004), SARA is often manifested in lower intakes and increased individual variability (Stock *et al*., 1995). Straw is given to maintain the rumen function and to reduce the impact of the high availability of starch, since it promotes chewing and rumination and consequently higher secretion of saliva, thus maintaining the buffering capacity of the rumen contents. However, its contribution to energy or protein input is almost negligible and it hampers feed management (Brown *et al*., 2006).

Several feeding strategies have been proposed to prevent acidosis in beef cattle. Increasing the proportion of forage increases salivation but dilutes the energy content of the ration. The processing of the concentrate may regulate intake rate and improve feed utilisation efficiency (Owens *et al*., 1997), although it can also imply a higher starch fermentation rate and a risk of decreasing rumen pH. Another strategy is ba-

* Corresponding author: mfonde@unizar.es
Received: 20-06-14. Accepted: 07-10-14.

Abbreviations used: BR (briquettes); CD (conventional diet); CP (crude protein); DM (dry matter); EE (ether extract); FCR (feed conversion ratio); LW (live weight); $LW^{0.75}$ (metabolic live weight); NDF (neutral detergent fibre); peNDF (physically effective NDF); SARA (subacute ruminal acidosis); VFA (volatile fatty acid).

sed on giving both concentrate and forage together as total mixed ration (Krause & Oetzel, 2006). Synchronisation of starch and fibre intake forces the animals to consume a fixed roughage proportion during the day, maintaining chewing and feed insalivation and minimising the risk of a sudden drop of rumen pH (González *et al*., 2012). This is appropriate for systems based on moderate levels of forage, but has not been tested for high intensive feeding using low levels of straw. Management of this practice might be favoured by packing a fixed proportion of concentrate and straw in pressed briquettes, further avoiding feed selection. Moreover, this presentation form might help to homogenise the daily intake pattern due to the more time needed to chew and disintegrate the briquettes. We aimed to evaluate the effect of offering a fixed proportion of concentrate and straw together in form of briquettes, compared with conventional feeding offering separately concentrate and straw, on performance, feed intake pattern and rumen pH in beef calves fed high-grain diets.

A 6-week experiment was carried out in the facilities of the Servicio de Experimentación Animal (University of Zaragoza, Spain). Thirty-two 8-month Holstein male cattle (385 ± 4.6 kg live weight-LW) were used for a performance trial. Another eight 9-month, rumen cannulated (88 mm length, 10 mm i.d.; DIVASA Farmavic S.A., Barcelona, Spain) Holstein male cattle (412 ± 10.4 kg LW) were used to monitor rumen pH. Animals were housed in individual 3.2 × 1.7 m pens provided with concentrate and roughage feeders. Animal care, handling and surgical procedures were approved by the Ethics Committee of the University of Zaragoza. Care and use of animals agreed to the Spanish Policy for Animal Protection RD 1201/05, meeting the EU Directive 86/609 on the protection of animals for experimental purposes.

The experimental diets were based on either concentrate and barley straw given separately *ad libitum* (conventional diet, CD) or a 87:13 mixture of the concentrate and barley straw, mixed and pressed in form of 30 × 30 × 30 mm briquettes (diet BR). The 13% proportion of straw was chosen as a compromise between average intake beef cattle (based on previous studies) and that allowing an adequate consistency in briquettes. Ingredient composition of concentrate in CD (g kg^{-1}) was: corn, 400; barley, 250; soybean meal, 120; sunflower meal, 80; wheat bran, 56; molasses, 50; palm oil, 23; $CaCO_3$, 12; $CaHPO_4$, 8; vitamin-mineral premix, 1. Ingredients proportions of BR were proportionally adjusted to include the straw. The concentrate composition in CD (g kg^{-1}) was: crude protein (CP), 157; ether extract (EE), 53.1; neutral detergent fibre (NDF), 163, whereas that of BR was: CP, 141; EE, 48; NDF, 246. The concentrate mixture in both CD and BR diets was ground to pass a 3.5 mm pore size sieve. Barley straw (g kg^{-1}: CP, 29; NDF, 735; acid detergent fibre, 522; lignin, 104) was given in CD as provided (5-20 cm length), and was ground in BR to about 30 mm for a homogeneous mixture and adequate consistency of the briquettes. Feeds were weekly sampled for further analysis. Concentrate in CD and briquettes were offered once daily, at 08:30, allowing for 10% daily residue, whereas straw in CD was offered thrice daily to ensure *ad libitum*. Concentrate residues were daily weighed and straw residues were weighed twice a week. Fresh water was freely available.

For the performance trial, intact cattle were randomly allocated to each of two experimental groups (n = 16) receiving the two dietary treatments. Feed adaptation lasted two weeks, and then feed intake and animal weight were weekly recorded (n = 4). Daily weight gain (kg d^{-1}) was calculated by regression of individual LW on time. The pattern of intake was monitored once a week, by emptying the individual feeders at 07:30, offering a known amount of feed at 08:30 and weighing the residues of concentrate after 1, 2, 4, 6, 8, 10, 12 and 24 h, and straw in CD after 4, 8, 12 and 24 h. The cannulated animals received CD or BR in two 21-d periods, following a change-over design. Both performance and cannulated trials were carried out simultaneously, with the same animal management and feeding protocol. On days 18 and 21 of each period, rumen contents (100 mL) were sampled before the morning feeding (08:30) and 4 and 8 h later, and pH was measured (model 507, CRISON Instruments SA, Barcelona, Spain). Feed intake and refusals were also monitored along sampling days at the same intervals.

Pooled feeds samples were ground to 1-mm size and analysed in duplicate. DM (Official method 934.01), organic matter (942.05), CP (976.05) and EE (2003.05) were determined according to AOAC (2005). NDF was analysed in an Ankom 220 Fibre Analyser (Ankom Technology, NY, USA) using α-amylase but not sodium sulphite, and results were expressed exclusive of residual ashes (Mertens, 2002a). Acid detergent fibre (AOAC, 2005) and lignin sulphuric (Robertson & Van Soest, 1981) were also determined. The particle size distribution of the concentrates was determined by dry sieving from triplicated 300 g samples, using 5 sieves from 0.15 to 2.4 mm pore diameter. Straw in BR was obtained by disaggregating several briquettes, and its length and that of straw given alone (diet CD) were measured.

The effect of the dietary treatment on performance results was analysed by ANOVA, using the GLM procedure of SAS 9.2 Statistical Package (Cary, NC, USA). Data for the pattern of intake and rumen pH were analysed by the MIXED procedure of SAS, considering the animal as the experimental unit. Differences were considered significant when $p \leq 0.05$, and tending to differ when $0.05 < p \leq 0.10$.

The concentrate particle size in CD was (on DM basis): below 0.15 mm, 8.1%; 0.15 to 0.30 mm, 13.9%; 0.31 to 0.60 mm, 22.5%; 0.61 to 1.20 mm, 30.6%; 1.21 to 2.40 mm, 22.5%; and over 2.40 mm, 2.4%. The same distribution was assumed for briquettes, since the same concentrate was used for their manufacturing. Straw particle size in the briquettes was: below 0.5 cm, 11.9%; 0.5 to 1.0 cm, 35.8%; 1.1 to 2.0 cm, 33.6%; and 2.1 to 5.0 cm, 18.7%. In contrast, only 1.9% of straw particles in CD were below 1.0 cm, 6.3% were between 1.1 and 5.0 cm and 75.8% larger than 10.0 cm.

Two animals from BR group in the performance trial suffered from bloat and were discarded. Despite animals were randomly allocated to the treatments (362 ± 4.9 kg for BR, n = 14, and 365 ± 6.0 kg for CD, n = 16), initial weight (Table 1) of those receiving CD was higher ($p = 0.016$) than in BR, because of a higher growth rate during the adaptation period (2.01 *vs.* 0.68 kg d^{-1}). Differences were maintained along the control period, the growth rate being 19% lower for BR than for CD ($p = 0.056$). Animals given CD also recorded a higher DM intake ($p < 0.001$), both in absolute terms and relative to metabolic LW. Average DM proportion of straw consumed in CD was 9.3 ± 0.42%, whereas in briquettes it was fixed at 13%. No treatment differences were recorded on the feed conversion ratio (FCR) ($p > 0.10$).

This work hypothesized that offering of concentrate and straw together in form of briquettes might be a way for preventing rumen acidosis in intensively reared calves. This should be achieved both by a synchronisation of concentrate and forage intake, avoiding feed selection, and by a more homogeneous pattern of daily feed intake, thus preventing a high punctual input of highly fermentable feed. This was partly achieved, since feed intake of intact cattle immediately after the morning offer was lower for BR (Fig. 1). Differences were mainly manifested in the first hour after feeding (2.81 *vs.* 1.75 kg h^{-1} for CD and BR; $p < 0.05$) and from 10 to 12 h (1.00 *vs.* 0.76 kg h^{-1}; $p < 0.05$). The average (n = 4) total feed intake was 11.7 and 8.7 kg fresh matter for cattle given CD and BR, respectively ($p < 0.01$). When expressed as a proportion of total intake (data not shown) diet CD promoted higher intake rate during the first hour (24.0 *vs.* 18.6%; $p < 0.001$), whereas the proportion of BR con-

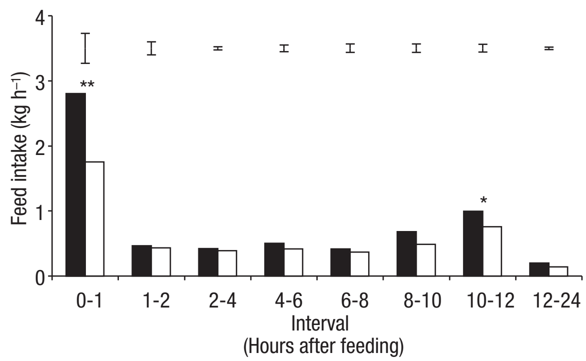

Figure 1. Total feed intake pattern of intact beef cattle given concentrate and straw separately (CD, black bars, n = 16) or together in form of briquettes (BR, white bars, n = 14). Upper bars represent the standard error of the means (n = 4). * $p < 0.05$, ** $p < 0.01$.

Table 1. Productive performances of intact beef cattle given concentrate and straw separately (CD, n = 16) or together in form of briquettes (BR, n = 14)

	CD	BR	SED	*p*-value
Initial live weight (kg)	394 ± 6.3	372 ± 5.4	8.402	0.016
Final live weight (kg)	443 ± 6.6	412 ± 7.2	9.716	0.004
Daily weight gain (kg d^{-1})	1.76 ± 0.099	1.43 ± 0.137	0.165	0.056
Total DM intake (kg d^{-1})	9.77 ± 0.273	7.08 ± 0.279	0.391	< 0.001
(g kg^{-1} $LW^{0.75}$ d^{-1})	105 ± 2.7	80 ± 2.7	3.854	< 0.001
Feed to gain ratio	5.82 ± 0.365	6.02 ± 1.035	1.037	0.851

$LW^{0.75}$: Metabolic live weight. SED: standard error of the difference.

Table 2. Daily pattern of total feed intake and rumen pH in cannulated beef cattle given concentrate and straw separately (CD) or together in form of briquettes (BR) in two consecutive periods (n = 8)

	Time	CD	BR	SED	*p*-value
Intake (kg d^{-1})		11.24	6.91	0.420	< 0.001
Intake (g kg^{-1} $LW^{0.75}$ d^{-1})		117.4	74.2	4.642	< 0.001
Rate of intake (g h^{-1})	0-4 h	871	666	92.033	0.046
	4-8 h	413	208	53.941	0.002
	8-24 h	384	215	30.838	< 0.001
Rumen pH	0 h	6.94	6.63	0.124	0.047
	4 h	5.98	5.64	0.082	0.006
	8 h	6.07	5.67	0.152	0.040
	Average	6.33	5.98	0.160	0.034

$LW^{0.75}$: Metabolic live weight. SED: standard error of the difference.

sumed tended to be higher from 2 to 4 h (4.5 *vs.* 3.6%; $p = 0.065$) and 6 to 8 h (4.2 *vs.* 3.6%; $p = 0.090$). The straw intake proportion in CD was around 13.3% in the first 4 h, and later diminished to 10.8 and 10.2% from 4 to 8 h and 6 to 12 h, reaching 7.0% from 12 to 24 h.

As in the performance trial, cannulated animals fed CD (Table 2) consumed more feed than BR ($p < 0.001$). These differences were manifested in 205 g during the first 4 h ($p = 0.046$) and 4 to 8 h ($p = 0.002$) and in 169 g in the period from 8 to 24 h ($p < 0.001$). The proportion of straw consumed in CD behaved similarly than in intact animals (12.7, 11.9 and 8.3%, on average, from 0 to 4 h, 4 to 8 h and 8 to 24 h, respectively). However, at all sampling times rumen pH (Table 2) was 0.3 to 0.4 units higher in CD than in BR ($p = 0.034$).

Although the individual pH pattern was not analysed statistically, it is worth considering the number of cases where pH was below 5.6, considered as a threshold for appearance of SARA (Owens *et al.,* 1998; Nagaraja & Titgemeyer, 2007). Thus, 4 h after feeding 18.7% of CD cattle showed a rumen pH below 5.6, all of them being recovered at 8 h, whereas 30.8 and 42.9% of cattle given BR had a pH lower than such level 4 and 8 h post-feeding, respectively. Therefore, animals given the BR diet were challenged at a higher extent for appearance of SARA. This unfavourable physiological condition would probably cause a lower intake with BR than with CD diet ($p < 0.001$), manifested in a trend for a lower weight gain ($p = 0.056$). Besides, a higher variability was observed in daily weight gain of BR compared with CD animals (variation coefficient of 0.357 *vs.* 0.224), which is not desirable in practical situations. However, the lower growth rate of BR cattle should also be partly attributed to a higher straw intake, which was fixed at 13% of DM intake whereas animals given CD only consumed 9.3%. In any case, no effect of processing was observed in the FCR.

The importance of the combined effect of the dietary proportion of fibre and its physical form in the forage given has been highlighted (Mertens, 1997) in high concentrate diets, where the threshold of feed particle size for being retained into the rumen and promote chewing should be around 2-3 mm (Ulyatt *et al.*, 1986). According with Mertens (2002b), the minimum physically effective NDF (peNDF) for ensuring appropriate rumen function and maximising growth of feedlot cattle should be 12 to 18%. Further, Fox & Tedeschi (2002) decreased this threshold to 7-10% for maintaining a rumen pH above 5.7. In our experiment, only 19% straw was longer than 2 cm and 34% was between 1 and 2 cm. In contrast, 82% of straw particles in CD were larger than 1 cm. This might justify differences between diets in rumination and rumen pH that explain feed intake and growth responses. However, when the peNDF was estimated from analysed NDF proportions, straw intake proportions of 9.3 and 13% for CD and BR and the physical effectiveness factors proposed by Mertens (2002b) for each proportion of straw particle size, it rendered values of 12.7 and 11.9% for CD and BR. These values are in the lowest range proposed by Mertens (2002b), but over the minimum recommended by Fox & Tedeschi (2002), and do not differ enough to explain the responses in terms of both pH and intake.

Differences between diets may also be explained by the possible self-regulation of the straw intake according to the physiological state of cattle when concentrate and straw were given separately, thus maintaining their rumen function stable by themselves. Previous studies have reported that sheep (Cooper *et al*., 1996) and beef calves (Moya *et al*., 2011) allowed for free access to dietary ingredients can sustain high levels of feed intake by keeping ruminal conditions within certain physiological limits, suggesting that ruminants are able to select diets according to their needs or preferences. In fact, intake of straw for CD cattle was highest in the first 4 h after the morning offer, probably in the latter half of this interval since the highest concentrate intake occurred in the first hour.

In conclusion, offering concentrate and straw as mixed diet in form of briquettes reduced the rate of intake during the first hour after feeding compared with conventional feeding. However, it did not result in a more stable fermentation in terms of rumen pH, which was, in fact, lower. Intake and productive performances were negatively affected probably due to both the low straw particle size of briquettes and to avoiding selection and distribution of straw intake along the day. Ensuring a higher straw particle size when manufacturing and/or including a higher proportion of straw in the briquettes would probably help to reduce the observed differences between treatments.

Acknowledgments

This work was supported by funds from the Spanish Ministry of Science and Innovation (MICINN, project ref. AGL2009-12026) and help of the Department of Industry and Innovation (Government of Aragón) and the European Social Fund. A. Gimeno and A. Al Alami were granted by the FPI program (MICINN) and the Spanish Agency for International Cooperation and Development, respectively.

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