

The effect of replacing dietary barley with dry corn gluten feed on the dynamics of ruminal pH

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ABSTRACT

The effect of replacing the barley with dry corn gluten feed (DCGF) on ruminal pH was studied on three fistulated dry cows, arranged in a 3x3 Latin square experimental design. The diets, fed once a day, consisted in alfalfa hay, ryegrass hay and barley-based compound feed. In the experimental groups, barley was partially (50%) or totally replaced by DCGF. Rumen pH was measured in rumen fluid sampled at 0, 2, 4, 6, 8, 10, 12 and 14 hours after the morning meal. Following pH parameters were calculated: mean pH, minimum pH, maximum pH, duration of pH decrease below 6.2, intensity of pH decrease below 6.2, area under pH curve and time when pH reached its minimum. Both partial and total replacement of barley with DCGF induced a significant increase of mean ruminal pH from 6.31 to 6.47 and 6.63, respectively. The differences are more marked when only biologically relevant decrease of pH, below 6.2, was considered. Thus, duration of pH decrease below 6.2 diminished from 6.25 hours in control group to 4.85 and 2.30 hours, respectively. Intensity of pH decrease below 6.2 also diminished, from 2.93 hours x pH units in control group, to 1.53 and 0.58 hours x pH units in experimental groups. It was concluded that replacement of barley with DCGF clearly increased the level of the ruminal pH, thus being as a possible solution in preventing the excessive post-prandial decrease of pH and its negative effects on ruminal activity.

Keywords: rumen, pH, corn gluten feed

INTRODUCTION

Intensive exploitation of ruminants leads to adverse side effects, among which digestive disorders such as subacute rumen acidosis (SARA). Despite the fact that the subject was extensively studied, the incidence of SARA in commercial farms is still high, leading to important economic losses (Garrett et al, 1997; Oetzel et al, 1999). This, together with the difficulty of its diagnosis (Garrett et al, 1999), shows the current need for recommendations that are effective in preventing decrease of ruminal pH below a safety level.

The mechanisms of acidosis onset are quite well documented. Among major causes is the high supply of readily available energy in diets. Frequent changes on the feeds market and other particular situations may force the farmers to frequently and sometimes rapidly change the animals' diets. A supplementary factor in South-Eastern Europe is the drought: in some years farmers have to heavily rely on concentrates rather than forages in order to formulate the diets for ruminants.

One of the potential solutions to alleviate adverse effects of high dietary proportion of concentrates is to make use of food industry by-products. Of these, corn gluten feed (CGF) – a by-product from the wet milling of corn, is a good candidate due to both its high fiber content and its high fiber digestibility. There are studies on the favorable effect of corn gluten feed in preventing SARA (Khrebiel, 1995; Sindt, 2003; Montgomery et al, 2004), but these were mostly performed on wet corn gluten feed. There are indications (starch content, processing conditions) that dry corn gluten feed (DCGF) may have different effect on ruminal pH than wet corn gluten feed (WCGF), as also suggested by Firkins et al, 1991. Most articles on CGF reported effect on average pH, whereas it was suggested (Sauvant et al., 1999; Kolver and de Veth, 2002) that average pH is an unsatisfactory descriptor of rumen dynamics – which are sensitive to factors involved in SARA, such as concentrate: forage ratio, type of concentrate feeds and their processing, presence of buffers, etc. (Sauvant, 1997; Oetzel, 2000).

The objective of this article is to assess the effect of replacing a source of readily digestible carbohydrates (such as barley) with DCGF on the dynamics of ruminal pH.

MATERIAL AND METHODS

Three ruminally cannulated dry cows were used in a 3×3 Latin square design in order to assess the effect of three treatments, 0%, 50% and 100% replacement of barley by dry corn gluten feed (B, B:DCGF, DCGF, respectively), on the dynamics of ruminal pH.

Animals were housed in individual digestibility stands and received one meal / day, at 7 a.m. In the first phase of the experiment, animals were fed a standard diet consisting in limited amounts of alfalfa hay, ryegrass hay and a specific compound feed (Table 1). The main phase of the experiment consisted in three periods of 14 days each, according to the experimental design. In each period, standard diet was suddenly replaced by the three experimental diets (B, B:DCGF, DCGF) for two days then animal were fed again the standard diet for the remaining 12 days. This allowed animals to readapt to the standard diets and rumen pH level to recover from eventual influence of experimental diets.

The nutritive values of the feed ingredients and the feeding requirements of the animals were calculated on the basis of equations recommended by Burlacu, 2002.

Table 1. Experimental diets

Ingredients / diets	Standard diet	diet B	diet B:DCGF	diet DCGF
alfalfa hay (kg/d)	2.2	0.9	1.0	1.0
ryegrass hay (kg/d)	2.3	1.0	1.0	1.0
molasses (kg/d)	0.1	-	-	-
compound feed (kg/d), composed of:	2.2	4.2	4.2	4.2
- barley	77%	77%	38.5%	-
- dry corn gluten feed	-	-	38.5%	77%
- sunflower meal	18%	18%	18%	18%
- vitamins & minerals	5%	5%	5%	5%

B = barley; DCGF = dry corn gluten feed

Rumen pH was measured in rumen fluid, sampled at 0, 2, 4, 6, 8, 10, 12 and 14 hours after the morning meal. The samples were collected with a high volume syringe, always from the same area of the rumen; the collected ruminal content (about 100 ml) was filtered through 4 layers of gauze and the pH was read with a Beckman pH meter, immediately after sampling (4 readings/sample). Samples were taken in two days consecutively, thus 8 observations were available for each treatment / period.

Following parameters were calculated: mean pH, minimum pH (pH min), maximum pH (pH max), duration of pH decrease below 6.2 (t<6.2), intensity of pH decrease below 6.2 (a<6.2), area under pH curve (auc), time when pH reached its minimum (t min). Duration and intensity of pH decrease were calculated using a Visual Basic script, by assuming linear evolution of pH between sampling times.

Statistical analyses were performed by GLM procedure followed by Tuckey test. Rumen pH parameters were compared using diet, animal, repetition, determination and interaction diet & animal as factors. Sampling time was also included as factor when averages of pH curves were compared.

RESULTS AND DISCUSSION

The diets fed during the experiment were integrally consumed and led to dietary nutritive supplies shown in Table 2.

As designed, diets brought the same energy supply (5.33 – 5.44 Milk Feeding Units); but the nature of the protein supply varied among experimental groups because of the higher content of dry corn gluten feed, comparing to barley.

The diets led to the postprandial pH evolution shown in Figure 1. The pH curves exhibited the same general trend: a fast drop in the first two hours after the morning meal, a minimum reached between 6 and 8 hours and a tendency to recover between 8 and 14 hours.

It is important to mention that curves in Figure 1 represent averages of 24 curves each, hiding the possible variability induced by animals, repetition, etc. An example of this variability is shown in Figure 2, by detailing the pH data by cow within dietary treatments.

Table 2. Nutritive supply of the experimental diets

	DM	MFU	PDIN	PDIE	Ca	P
standard diet	6008.3	5.33	484.8	434.2	64.3	31.0
diet B	5411.4	5.33	493.5	408.9	45.3	39.9
diet B:DCGF	5534.9	5.44	601.8	479.9	46.6	39.6
diet DCGF	5484.2	5.43	692.9	539.8	44.2	38.8

B = barley; DCGF = dry corn gluten feed; DM = dry mater; MFU = milk feeding units; PDIN = intestinal digestible protein allowed by nitrogen; PDIE = intestinal digestible protein allowed by energy

It is obvious that cow 3 (marked with triangles in Figure 2) exhibited a lower pH than the other two cows. Also, it has to be mentioned that Figure 1 does not display the correct minimum pH, it only show the averages at a certain hour. Because minimum pH occurred at various post-prandial times, the correct value is the average of minimum pH of each pH curve recorded and is presented in Table 3, where the main parameters of the post-prandial evolution of the ruminal pH are also presented.

Replacement of barley with dry corn gluten feed led to a significant increase of the mean level of the ruminal pH: +0.16 pH units in case of partial replacement and + 0.32 units in case of total replacement. The increase is consistent with that obtained by Sindt, 2003, by increasing the WCGF proportion of diet from 25% to 45% (+0.11 pH units). Increase of pH associated with the replacement of starch-rich feed (corn) with WCGF was also observed by Montgomery, 2004.

It has to be noted that although the concentrate:forage ratio changed from 33% to 66%, the cows in our study were not on SARA conditions. A mean pH of more than 6.3 looks reassuring. However, the mean pH hinders information that is relevant for ruminal fermentation. The negative effects of low pH on ruminal activity start below some safety thresholds (6.2; 6.0; 5.8; 5.5) established through in vitro trials (Shriver et al., 1986; Slyter and Rumsey, 1991; Russell and Wilson, 1996) and confirmed through in vivo trials (Mould et al, 1983; Martin and Michalet-Doreau, 1995). As the mean pH of all experimental groups is above 6.3, this value offers no indication on composing values lower than 6.2 (the highest threshold with biological significance).

On the other hand, the other pH parameters offered more insight. Thus, only the total replace of barley by DCGF influenced the minimum pH, which increased with 0.32 pH units. The partial replacement had no significant effect on minimum pH. However, minimum pH, although calculated from 24 values, it relies only on punctual measurements. As trials with continuous pH monitoring revealed quite high irregularities of pH daily evolution (Maekawa,

2002) and our study monitored pH at 2 hours intervals only, the results on minimum pH are to be interpreted with caution.

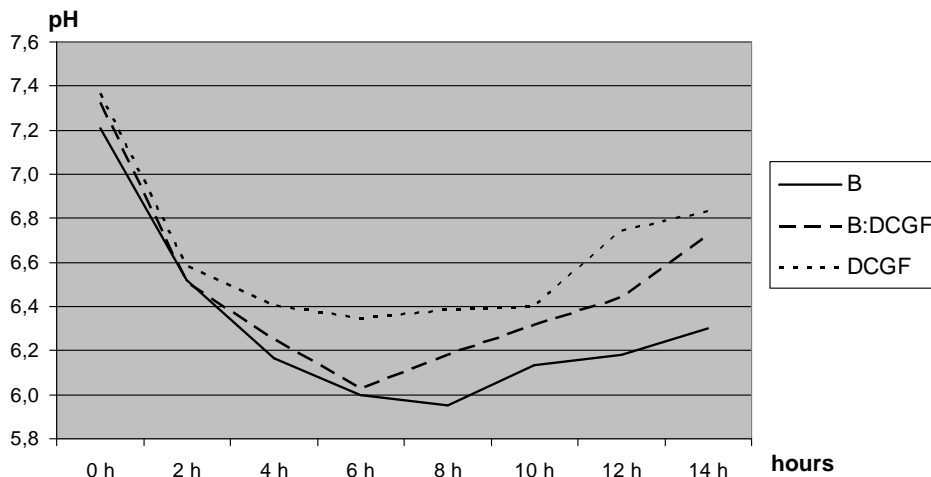


Figure 1. Post-prandial evolution of ruminal pH, clustered by diet

Effects of post-prandial time when pH reaches its minimum, although significant, are not systematic: while minimum pH is reached at 9.33 hours in control group, it takes only 6.5 hours in case of partial replacement and 7.33 hours in case of total replacement.

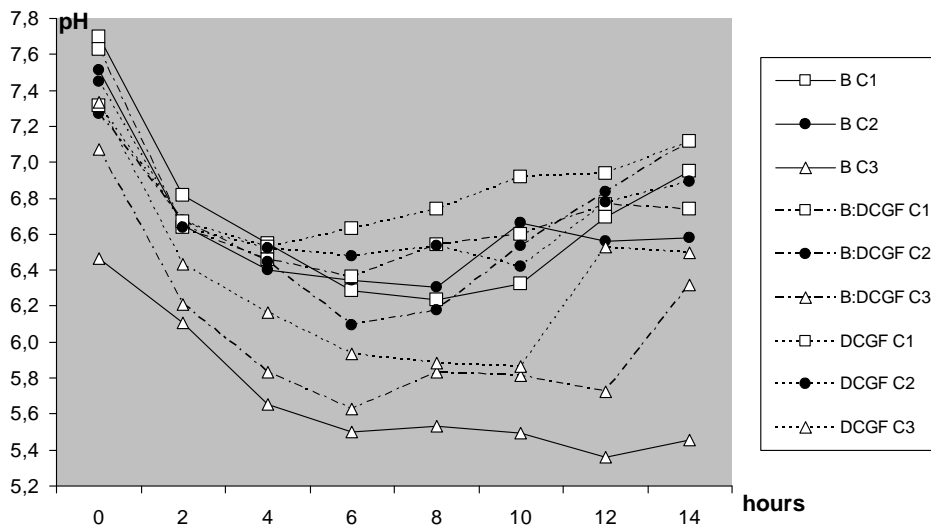


Figure 2. Post-prandial evolution of ruminal pH, detailed by diet and cow (B=barley, DCGF = dry corn gluten feed, C = cow)

A possible explanation of these effects can be the shift of ruminal fermentations, leading to various typologies of ruminal pH evolution (e.g. the time of minimum pH become less relevant in case of flat pH curves).

Table 3. Effect of diets on the pH parameters at rumen level

	N	Diet B	Diet B:DCGF	Diet DCGF
mean pH	192	6.308 ^a ± 0.620	6.471 ^b ± 0.530	6.634 ^c ± 0.428
pH min	24	5.893 ^a ± 0.440	5.957 ^a ± 0.352	6.216 ^b ± 0.390
pH max	24	7.231 ^a ± 0.553	7.324 ^b ± 0.247	7.365 ^b ± 0.079
t < pH 6.2	24	6.25 ^a ± 5.44	4.85 ^b ± 4.83	2.30 ^c ± 3.33
a < pH 6.2	24	2.93 ^a ± 3.55	1.63 ^b ± 1.99	0.58 ^c ± 0.84
t min	24	9.33 ^a ± 1.93	6.50 ^b ± 1.79	7.33 ^c ± 2.80
auc	24	87.42 ^a ± 6.26	89.49 ^b ± 4.53	91.94 ^c ± 3.40

B = barley; DCGF = dry corn gluten feed; t < pH 6.2 = duration of pH decrease below 6.2 (hours), a < pH 6.2 = intensity of ruminal decrease below 6.2 (hours x pH units), auc=area under pH curve

The duration of pH decrease below 6.2, a parameter which is more reliable and have biological significance, was strongly influenced by total or partial replacement of barley with DCGF: it was diminished by 22% in case of partial replacement and almost three times in case of total replacement. The effects are more marked in the case of area below 6.2: partial replacement halved this parameter and total replacement diminished it more than five times.

Khrebiel, 1995, found also a diminution of area below pH 6.0 values when corn was partial (50%) or totally replaced by WCGF, but this diminution was lower than in our study: from 11.7 to 8.4 and 8.3 hours x pH units, respectively (only 26-27%). The inconsistency arise from the difference (corn versus barley) in starch nature and degradability (Sauvant, 2002), but also from the choice of the threshold in relation to minimum pH. In our trial minimum pH and pH threshold were closer to each other than in the mentioned article.

Most articles report effects of CGF when replacing fiber sources, such as forages. These authors usually report only slight decrease of pH (Hannah, 1990; Fellner & Belyea, 1991), which suggests CGF can be used as a substitute of fiber source. Comparing to barley, NDF content is much higher: 34% versus 18%. However, the most determining factor seems to be the starch content, which is much lower in the case of DCGF comparing to barley (18% versus 52%).

The fact that duration and intensity of pH decrease below 6.2 were influenced by the replacement of barley with DCGF, without changing the energy supply of the diet, shows the potential of the later to act as energy feed ingredient which help preventing the unsafe decrease of pH.

Further studies are required in order to assess the effects of DCGF in diagnosed SARA conditions and the estimate the effects on animal productive performances.

CONCLUSIONS

Partial (50%) or total replacement of barley with dry corn gluten feed in cow's diet consisting in alfalfa hay, ryegrass hay and compound feed induced a significant increase of the level of ruminal pH.

Mean pH increased from 6.31 in control group to 6.47 and 6.63 in the DCGF groups, respectively. Consequently, the duration of pH decrease below 6.2 and the intensity of pH decrease diminished: from 6.25 hours in control group to 4.85 and 2.30 hours in DCGF groups and from 2.93 hours x pH units in control group, to 1.53 and 0.58 hours x pH units in DCGF groups.

It is concluded that replacement of barley with DCGF may help in preventing the excessive post-prandial decrease of ruminal pH, below unsafe levels.

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