THE EFFECTS OF REPLACING CORN GRAINS WITH DRY SUGAR BEET PULP ON THE INTEGRATIVE PARAMETERS OF RUMEN PH POSTPRANDIAL DYNAMICS

CATALIN DRAGOMIR, SMARANDA POP
National Institute for Research Development in Animal Biology and Nutrition,
Balotesti, Romania

Sugar beet pulp is well known as an alternative source of energy for ruminants; according to **Burlacu** (2002) although it its energy value is slightly lower (~ 90%) comparing to classical sources such as corn grain, it has a much higher content of fibers (at least 15%, comparing to only 2.6% in corn). This compromise between a good content of digestible energy and a high content of fiber makes sugar beet pulp a good candidate as alternative to more acidogenic feeds, such as cereals. This advantage is clear when replaces feeds such as barley, where energy content and its overall availability in rumen are similar to sugar beet pulp (± 5%), and the only major difference from the acidosis perspective is the digestible fiber supply of the later. When replaces corn it is relevant that, beside higher fiber content, sugar beet pulp has also a higher content of fermentable organic matter (76% versus 61% in corn) which is supposed to contribute to the decrease of rumen pH (**Sauvant**, 1997). In this context, the objective of the current study is to assess the effect of replacement of corn by sugar beet pulp in cows' diets on the post-prandial evolution of rumen. As mean pH is not a comprehensive descriptor of rumen pH (**Sauvant et al.,** 1999; **Kolver et al.,** 2002), integrative parameters of rumen pH evolution (**Dragomir et al.,** 2008) were also studied.

MATERIAL AND METHODS

Two fistulated cows were used in a 2 x 2 Latin square design in order to assess the effects of the main energy ingredients of the diet (corn versus sugar beet pulp), at two levels of concentrates (6 and 8 kg of compound feed). The experimental design is shown in Table 1.

A standard diet, designed to ensure optimal rumen functions (**B M Doreau & Ould Bah,** 1992), consisting in 6.5 kg alfalfa hay, 3.0 kg compound feed (based on barley and sunflower meal) and 0.1 kg molasses wad fed, in two meals daily, for at least 10 days before the experiment, between the two experimental periods and after the experiment, in order to allow rumen environment to stabilize after potential effects of the experimental diets.

Experimental diets, fed in one meal/day, consisted in alfalfa hay (1.8 kg / day for all groups) and compound feed based on corn (control group) or sugar beet pulp (experimental group) and wheat bran. The compound feed in the control group consisted in 71.5% corn, 24.7% wheat bran and 3.8% vitamins

Table 1. **Experimental design**

Period	before trial	first experimental period		recovery period	second experimental period	
		6 kg CF	8 kg CF		6 kg CF	8 kg CF
Cow 1	standard diet	corn diet	corn diet	standard diet	sugar beet pulp diet	sugar beet pulp diet
Cow 2	standard diet	sugar beet pulp diet	sugar beet pulp diet	standard diet	corn diet	corn diet

& minerals; in the experimental group the structure of compound feed consisted in 71.4% sugar beet pulp, 24.6% wheat bran and 4% vitamins and minerals (adapted to the specific of sugar beet). Beside inclusion in the compound feed, 0.3 kg of sugar beet pulp was supplementary fed in experimental group, in order to ensure equal energy and protein supplies of the diets (Table 2).

In both experimental periods, standard diets were suddenly replaced by the experimental diets, at the overall level of 6 kg compound feed / head in the first day and 8 kg compound feed / head in the second day.

pH measurements were performed on ruminal fluid samples collected at 2, 4, 6, 8, 10 and 12 hours after the morning feeding in the days when experimental diets were fed. 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.

For each series of values describing the 12 hours post-prandial evolution of pH, several parameters were calculated: average pH; minimal pH; maximal pH, duration of pH decrease below several pH thresholds (t < 6.2; 6.0; 5.8; 5.5), measured in hours; intensity of pH decrease below the same thresholds, measured in hours x pH units as the areas between the pH curve and the threshold lines (a < 6.2; 6.0; 5.8; 5.5); area under curve (a.u.c.), representing the area between the pH curve and the 0-x axis, measured in hours x pH units. Also, the initial slope of pH decrease was calculated by fitting third degree polynomial equations to each pH series and replacing the unknown term with 0 in the first derivatives of these equations (**Dragomir,** 2008).

The pH thresholds were chosen on the bibliographic basis, from the reported effects of pH decrease on the microorganisms growth in vitro (**Mould et al.,** 1983; **Martin and Michalet-Doreau,** 1995) or on relevant rumen functions such as cellulolysis or microbial proteosynthesis (S**hriver et al.,** 1986; **Slyter and Rumsey,** 1991). The pH parameters were calculated in Microsoft Excel, using a macro written in Visual Basic and the results were processed statistically by ANOVA procedure (**Minitab**, 2000).

RESULTS AND DISCUSSIONS

The high variability between animals observed in previous experiments and the small number of available animals imposed the choice of the Latin square experimental design. The effect of animal on the postprandial evolution of rumen pH can be observed in Fig. 1; one of the cows was more resistant to the decrease of the pH, in all four feeding situations.

As expected, increased amounts of ingested concentrates (based on energetic ingredients) led to a clear effect on rumen pH postprandial evolution, as shown by its graphical representations in Fig. 2. The shape of these graphics is usually determined by four independent components that can be related to the dietary factors (**Dragomir,** 2008): the general level of the curves, the general slope of pH decrease, the deepness of the curves and the asymmetry of the curves (presence / absence of a lag time). The first three components were clearly involved in determin-

Table 2. **Structure and nutritive supplies of the experimental diets**

	Corn group CF level - 6 kg	Sugar beet pulp group CF level - 6 kg	Corn group CF level - 8 kg	Sugar beet pulp group CF level - 6 kg
Alfalfa hay (kg)	1.8	1.8	1.8	1.8
Compound feed (kg)	8.1	9	6.2	6.7
Sugar beet pulp*	0	0.3	0	0.3
Dry mater supply (g)	6908.8	7748.3	8557.1	9791.4
Milk Feed Units	6.94	6.77	8.81	8.71
PDIN (g)	570.4	550.8	697.9	681
PDIE (g)	685.7	715.4	856.9	907.7

* fed supplementary to the sugar beet pulp included in the compound feed (CF)

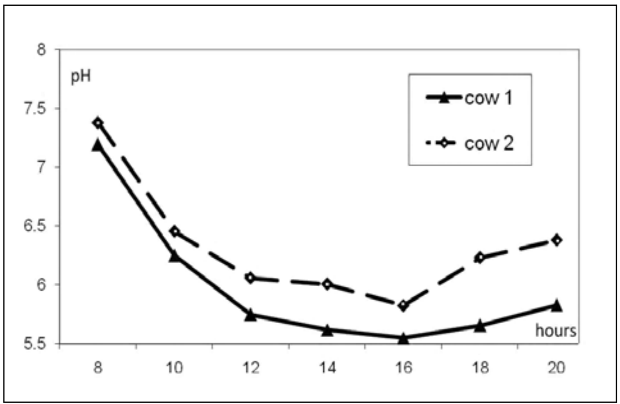

Fig. 1. **Individual variability of rumen postprandial pH dynamics**

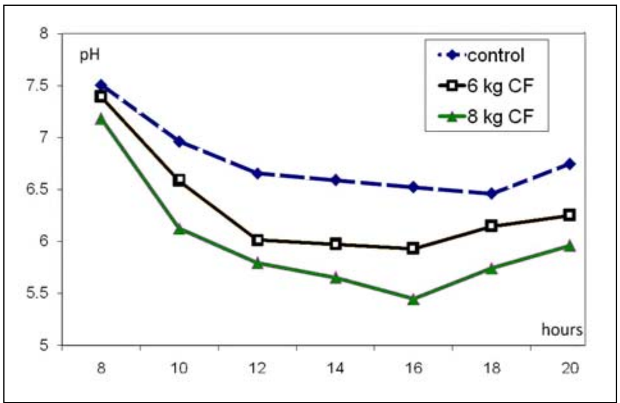

Fig. 2. **The effect of concentrates' dietary proportion on the rumen postprandial pH dynamics**

ing the shape of pH curves associated with the proportion of dietary concentrates. Thus, increasing the level of concentrates led to clear effects on the general level of pH curves, as summarized by average pH, which decreased with 0.16 units / kg of compound feed added in diet, approximately. The same trend was observed for minimal and maximal pH; in fact all points of the pH curves followed the same pattern. On the other hand, slope of pH decrease changed when switching from control to experimental diets (from -0.287 to double), but no difference between the two proportion of concentrates was detected (-0.555 vs. -0.556), which is consistent with the observation mentioned above. The deepness of pH curves is partly expressed by area under threshold, which was more extended for the higher level of concentrates, irrespective of the considered threshold.

It is important to mention that the pH curves did not recover to the initial values during the measurements period (12 hours after the meal); this might have lead to underestimation of the threshold-related parameters in several cases, but with little influence on the results.

While all threshold-related parameters were 0 when standard diet was fed, feeding 6 kg of compound feeds led to a marked increase of duration and intensity of pH decrease under safe levels (Table 3). Thus, pH decreased for 1.01, 2.39, 3.88 and 5.88 hours under the pH thresholds of 5.5, 5.8, 6.0 and 6.2, respectively. This means that for these periods some rumen processes were impaired or at least were less efficient than optimal (**Russell and Wilson,** 1996). It is difficult to quantify the extent of these effects on rumen functions, as long as even the setting of threshold level is still in debate. However, a too severe decrease becomes relevant from the point of view of feeding efficiency. Thus, feeding 8 kg of compound feeds led to almost double decrease of pH below mentioned thresholds, for 1.86, 6.58, 8.49 and 9.84 hours (the last two being underestimated). Such long periods of pH decrease are probably associated with losses of efficiency; the effects on the level of productive performances may be hindered by other factors, but effects on nutrient consumptions per unit of animal production are to be expected.

Differences induced by switching the level of compound feed from 6 to 8 kg were statistically significant (P<0.001), except for area below 5.5 and for the initial slope of pH decrease. In the first case, although absolute difference was high (almost double), statistical analysis was impaired by the very high variability of the data, resulting from interaction between level of threshold and level of minimum pH. In the second case, as mentioned, the averages corresponding to the two levels of compound feeds were almost identical.

The effect of the nature of energetic ingredient of the diets is shown in Fig. 3. For both experimental diets pH, all values were much lower than for the standard diet (which is also an effect of the amount of ingested compound feed: from 3 kg to an average of ~ 7 kg / head * day). Differently than the effect of concentrate level, nature of energetic ingredient led

Table 3. **The effect of concentrates' dietary proportion on the descriptive parameters of the rumen pH postprandial evolution**

Parameter*	Control group	6 kg CF group	8 kg CF group
average pH (pH units)	6.78 ± 0.01	6.33 ± 0.23	5.99 ± 0.12
min pH (pH units)	6.29 ± 0.11	5.86 ± 0.29	5.45 ± 0.04
max pH (pH units)	7.51 ± 0.03	7.39 ± 0.06	7.18 ± 0.13
t < 5.5 (hours)	0	1.01 ± 1.51	1.86 ± 1.41
a < 5.5 (hours x pH units)	0	0.05 ± 0.07	0.06 ± 0.04
t < 5.8 (hours)	0	2.39 ± 2.64	6.58 ± 2.18
a < 5.8 (hours x pH units)	0	0.55 ± 0.8	1.32 ± 0.59
t < 6.0 (hours)	0	3.89 ± 3.18	8.49 ± 1.29
a < 6.0 (hours x pH units)	0	1.18 ± 1.29	2.83 ± 0.94
t < 6.2 (hours)	0.04 ± 0.05	5.88 ± 3.24	9.84 ± 0.51
a < 6.2 (hours x pH units)	0	2.16 ± 1.77	4.67 ± 1.12
a.u.c. (hours x pH units)	80.64 ± 0.13	74.94 ± 2.88	70.67 ± 1.37

* "t < "= time while pH is lower than a threshold value; "a<" = intensity of pH decrease, measured as area between pH curve and the threshold line; "a.u.c." = area under curve, represents the area between pH curve and 0-x axis

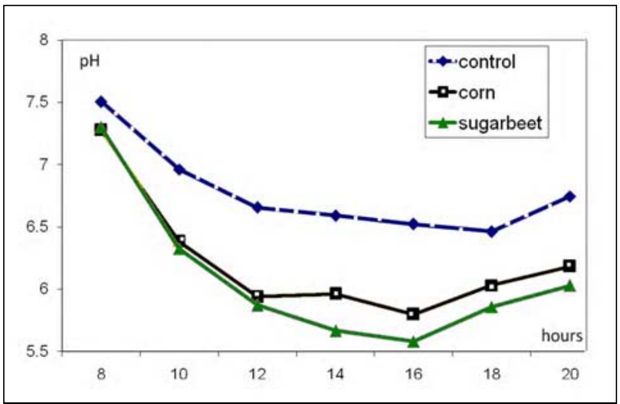

Fig. 3. **The effect of energy source on the rumen postprandial pH dynamics**

to less marked effects on graphical representation of rumen pH postprandial evolution. Of the four mentioned components determining the shape of curves, the general level and deepness are most likely to have interfered. Thus, replacement of corn by sugar beet pulp led to a decrease of average pH by 0.14 units. The same effect occurred for minimal pH; on the contrary maximum pH was unchanged (7.3 versus 7.28). First part of the slope of pH decrease was practically identical, which led to rather small differences in the general slope, of 7%, from -0.537 for corn to -0.575 for sugar beet pulp. Differences in threshold-related parameters were more marked, in the group that received sugar beet pulp diet, decrease of pH below thresholds lasted much longer that for corn group (with 21%, 32%, 60% and 179% for t<5.5, 5.8, 6.0 and 6.2, respectively). Differences of 50-120% were also noticed for intensity of pH decrease.

On the other hand, these values are to be judged from the point of view of biological significance. For example, in case of area below 5.5, difference from 0.04 to 0.07 hours * pH units has no relevance, as in both cases the values are too low to have a biological impact, from the perspective of this threshold. In the same manner, 8.59 versus 7.12 hours of pH below the threshold of 6.2 seem rather moderate, from the perspective of rumen ecosystem.

Differences induced by the nature of energy ingredient of the diet were statistically significant for all parameters, except for area below 5.5, where a tendency was noticed (*P*=0.052), maximum pH (*P*=0.326) and initial slope of pH decrease (*P*=0.273).

This is contrary to the results of **Huhtanen** (1998) and **Lettat et al.** (2010): first one reported no difference in rumen pH, when sugar beet pulp replaced barley; the second ones observed even a consistent

Table 4. **The effect of dietary energy nature on the descriptive parameters of the rumen pH postprandial evolution**

Parameter*	Control group	Corn group	Sugar beet group
average pH (pH units)	6.78 ± 0.01	6.23 ± 0.21	6.09 ± 0,2
min pH (pH units)	6.29 ± 0.11	5.72 ± 0.31	5.58 ± 0.18
max pH (pH units)	7.51 ± 0.03	7.28 ± 0.13	7.3 ± 0.11
t < 5.5 (hours)	0	0.76 ± 0.76	2.11 ± 2.05
a < 5.5 (hours x pH units)	0	0.04 ± 0.04	0.07 ± 0.07
t < 5.8 (hours)	0	3.45 ± 2.53	5.51 ± 2.95
a < 5.8 (hours x pH units)	0	0.58 ± 0.55	1.28 ± 0.89
t < 6.0 (hours)	0	5.33 ± 2.67	7.04 ± 2.81
a < 6.0 (hours x pH units)	0	1.48 ± 1.04	2.52 ± 1.45
t < 6.2 (hours)	0.04 ± 0.05	7.12 ± 3.56	8.59 ± 1.66
a < 6.2 (hours x pH units)	0	2.71 ± 1.53	4.11 ± 1.75
a.u.c. (hours x pH units)	80.64 ± 0.13	73.69 ± 2.72	71.93 ± 2.3

* "t < "= time while pH is lower than a threshold value; "a<" = intensity of pH decrease, measured as area between pH curve and the threshold line; "a.u.c." = area under curve, represents the area between pH curve and 0-x axis

increase of pH, when sugar beet pulp replaced corn.

The difference in results may by induced by differences in processing technologies of sugar beet – related to the efficiency of extraction. As previously mentioned, the tested product has a high content of fermentable organic matter (higher than corn), which might have been contributed to the decrease of pH, overriding the buffering effects of fibers. However, change of rumen pH evolution is only a part of the effects of sugar beet pulp at rumen level, Other effects, such those on microbial proteosynthesis, are to be considered in decision to replace classical energy ingredient with sugar beet pulp.

CONCLUSIONS

Replacement of corn by sugar beet pulp in diets based on alfalfa hay and high levels of concentrates let to a slight decrease of average rumen pH, from 6.22 in corn group to 6.09 in sugar beet pulp group (-2.2%). The differences were higher when parameters of rumen pH evolution were considered, except for slope of pH decrease: 20% higher for time below pH 6.2, 50% higher for area below pH 6.3 or even higher for other thresholds. These differences are to be considered in association with known thresholds relevant for various rumen processes.

REFERENCES

1. **Burlacu, Gh., Cavache A., Burlacu R.,** 2002. Productive potential of feeds and their use. Ed. Ceres, Bucuresti
2. **Dragomir, C., D. Sauvant, J.-L. Peyraud, S. Giger-Reverdin, B. Michalet-Doreau,** 2008. Meta-analysis of 0 to 8 h post-prandial evolution of ruminal pH. Animal, Volume 2, Issue 10, pp 1437-1448
3. **Huhtanen, P.,** 1988. The effects of barley, unmolassed sugar-beet pulp and molasses supplements on organic matter, nitrogen and fibre digestion in the rumen of cattle given a silage diet. Animal Feed Science and Technology, 20:4, 259-278
4. **Kolver E. S. and de Veth M. J.,** 2002. Prediction of Ruminal pH from Pasture-Based Diets. J. Dairy Sci. 85, 1255-1266
5. **Lettat, A., P. Nozière, M. Silberberg, D. P. Morgavi, C. Berger and C. Martin,** 2010. Experimental feed induction of ruminal lactic, propionic, or butyric acidosis in sheep. J. Anim Sci., 88:3041-3046
6. **Martin, C. and Michalet-Doreau B.,** 1995. Variations in mass and enzyme activity of rumen

microorganisms: effect of barley and buffer supplements. Journal of the Science of Food and Agriculture 67, 407–413.
7. **Michalet-Doreau, B., Ould-Bah M.Y.,** 1992. In vitro and in sacco methods for the estimation of dietary nitrogen degradability in the rumen: a review. Animal Feed Science and Technology, 40, 57-86
8. Minitab 2000. Minitab 13.20 for Windows. Minitab Inc., State College, PA, USA.
9. **Mould, F. L., Orskov E. R. and Mann S. O.,** 1983. Associative effects of mixed feeds. 1. Effects of type and level of supplementation and the influence of rumen pH on cellulolysis in vivo and dry matter digestion of various roughages. Animal Feed Science and Technology 10, 15–30.
10. **Russell, J. B. and Wilson D. B.,** 1996. Why are ruminal cellulolytic bacteria unable to digest cellulose at low pH? Journal of Dairy Science 79, 1503–1509.
11. **Sauvant, D.,** 1997. Consequences digestives et zootechniques des variations de la vitesse de digestion de l'amidon chez les ruminants. INRA Prod. Anim., 10, 4, 287-300
12. **Sauvant, D., Meschy F., Mertens D.,** 1999. Les composantes de l'acidose ruminale et les effets acidogènes des rations. INRA Prod. Anim., 12, 1, 49-60
13. **Shriver, B. J., Hoover W. H., Sargent J. P., Crawford R. J. and Thayne W. V.** 1986. Fermentation of a high concentrate diet as affected by ruminal pH and digesta flow. Journal of Dairy Science 69, 413–419.
14. **Slyter, I. L. and Rumsey T. S.,** 1991. Effect of coliform bacteria, feed deprivation and pH on ruminal D-lactic acid production by steer or continuous-culture microbial populations changed from forage to concentrates. Journal of Animal Science 69, 3055–3066.

THE EFFECTS OF REPLACING CORN GRAINS WITH DRY SUGAR BEET PULP ON THE INTEGRATIVE PARAMETERS OF RUMEN PH POSTPRANDIAL DYNAMICS

C. Dragomir, S. Pop
National Institute for Research Development in Animal Biology and Nutrition, Balotesti, Romania

The effect of replacing corn grains with dry sugar beet pulp on the postprandial dynamics of rumen pH was assessed on two fistulated cows, in a 2 x 2 Latin square experimental design. A standard diet, designed to ensure optimal rumen function, was suddenly replaced by the experimental diets consisting in 2 kg alfalfa hay and 6 or 8 kg of compound feed based either on corn (control) or sugar beet pulp (experimental). Rumen pH was measured for 12 hours after the morning meal, on rumen fluid samples taken every two hours and synthetic parameters of pH evolution were also calculated. The results highlighted a noticeable animal-related variability of pH dynamics (0.2 pH units difference between averages of cows), a strong effect of the compound feed level (- 0.16 pH units / kg of supplementary compound feed, approximately) and a rather small effect of the replacement of corn by sugar beet pulp (0.13 pH units). The differences were more noticeable when expressed in time or area under pH thresholds.

Key words: *rumen pH, sugar beet pulp, cows*

ACKNOWLEDGEMENTS
The experiment was performed within the research project PN.09-38.03.01/2009, financed by the National Authority for Scientific Research (ANCS).