

# Dietary Characteristics Affecting Ruminal Acidosis

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## Introduction

Ruminal acidosis is a concern in modern nutrition of ruminants because increased production is typically associated with increased proportions of concentrates in diets. The decreased chewing activity and salivary buffer secretion when ground, low fiber concentrates are consumed, coupled with the rapid digestion rate of concentrate carbohydrates can result in dramatically decreased ruminal pH. Ruminal acidosis can lead to several production disorders such as negative digestive interactions, reduced milk fat content, and digestive and metabolic pathologies. Mild acidosis occurs when ruminal pH is between 5.5 and 6.25 and severe acidosis occurs when pH is less than 5.5. When ruminal pH is below 6.0, fiber digestion is decreased, the ratio of acetate to propionate is shifted to values below 2.0; and milk fat production is often depressed. Moderate to severe acidosis is often associated with foot problems and metabolic disorders that affect the long term health of lactating females.

Our objective was to systematically study published data on ruminal pH with the purpose of developing quantitative relationships between diet characteristics and ruminal pH. Both acid-producing as well as the buffering or neutralizing effects of the diet were investigated to identify ways of estimating the risks associated with ruminal acidosis which could be used to create new or improved systems for formulating dairy rations.

## Materials and Methods

A database of digestion information was compiled from 223 publications that reported results for 945 combinations of animal and treatment. Because of differences among publications in methods and experimental approaches, unique codes were assigned each experiment data set and used as a classification variable in statistical analyses. Two statistical approaches were used for meta analyses. First, an

overall or global relationship (**g**) was determined without removing the variation among experiments. Second, the global relationship was adjusted for among-experiment differences by including the experiment class variable in the regression model to obtain a pooled within-experiment relationship (**p**). The weighted average intercept is reported for pooled regression models. In each statistical analysis, the number of combinations of animals and treatments (**n**), number of experimental classes (**n<sub>exp</sub>**), correlation coefficient (**r**), and standard error of regression (**SE**) were reported.

## Results and Discussion

For most published research, the criteria for measuring ruminal acidosis was mean ruminal pH that was averaged over 24 h or less. Because fiber digestion is inhibited during the time when ruminal pH is below 6.0 (**pH < 6**), some research also reported the duration that pH was at or below this value. These two criteria of ruminal acidosis were highly correlated:

$\text{pH} < 6 \text{ (min/d)} = 1224 - 1316 \text{ (pH } -5.5)$ ;  
 $n = 80, n_{\text{exp}} = 35, r(\text{p}) = -0.94, \text{SE}(\text{p}) = 112.$

For pH to remain above 6.0 throughout the day, average pH must be 6.4 or higher. An average threshold pH of 6.25 would result in pH being less than 6 for about 4 h/d. Several ruminal and dietary characteristics were related to this index of rumen irregularity (min/d that **pH < 6**) including ruminal ammonia [ $r(\text{p}) = -0.91$ ], ruminal acetate to propionate ratio [ $r(\text{p}) = -0.91$ ], dietary crude protein [ $r(\text{p}) = -0.94$ ], and dietary starch [ $r(\text{p}) = +0.91$ ].

The primary factor acidifying the rumen is concentration (mM) of volatile fatty acids (**VFA**). The global relationship in this data set was:

$\text{pH} = 7.20 - .0091 \text{ (VFA)}$ ;  
 $n = 406, r(\text{g}) = -0.75, \text{SE}(\text{g}) = 0.25.$

The relatively large SE(g) of this equation suggests that at a given VFA concentration, pH can vary substantially. Although dietary starch was not related to ruminal pH [ $r(g) = +0.17$ ], it was related to the residual variation between pH and VFA. A significant portion of this residual variation (**RV**) can be explained by percentage of starch in ration dry matter (**Starch**) and mg/l of ruminal ammonia (**NH<sub>3</sub>**):

$$RV = 0.15 - .011 (\text{Starch}) + .0014 (\text{NH}_3);$$
$$n = 120, n_{exp} = 49, R^2(p) = 0.98, SE(p) = 0.19.$$

Numerous factors affect ruminal pH including fermentable organic matter, ruminally digestible starch, amount and composition of fiber and nonfibrous carbohydrate, and particle size and buffering capacity in the diet, intake of silage and total dry matter, rate of feed intake, chewing activity, capture of hydrogen ions by products of digestion, changes in the stoichiometry of fermentation, and absorption or passage of VFA. Although each of these factors may play a role in the phenomenon of ruminal pH, we propose a simple two-stage approach to estimating pH based on easily measured or estimated variables.

Stage 1. Establish a baseline ruminal pH that is estimated from the intake of concentrates and forages which every nutritionist should be able to measure or estimate. From the database we derived an equation based on the intake of forage (**%FI**) and concentrate (**%CI**) expressed as a %BW/d:

$$pH = 6.54 - 0.054 (\%FI) - 0.18 (\%CI);$$
$$n = 527, r(g) = 0.42, SE = 0.28.$$

Using the relatively simple variables of %FI and %CI, this equation takes into account the effects of intake and differences in the fermentability and particle size between forages and concentrates.

Stage 2. Adjust the baseline ruminal pH for differences in percentage NDF, particle density (**PD**) which is the

inverse of mean particle size (mm), and percentage of ruminally degradable starch (**RDS**) in the ration:

$$DpH = 0.60 [(\log_{10} \text{NDF}) - 1.57];$$
$$n = 484, SE = 0.13,$$
$$DpH = -0.06 (DP - 0.42);$$
$$n = 71, SE = 0.15, \text{ and}$$
$$DpH = -0.012 (RDS - 17.2);$$
$$n = 117, SE = 0.10.$$

## Summary and Conclusion

Equations developed from a database of ruminal pH data compiled from the literature can be used to estimate the risk of mild or severe acidosis from readily available information. Assuming a minimum threshold for ruminal pH of 6.25 for animals of moderate production levels, it is possible to define corresponding recommendations for various dietary characteristics. Thus, it is recommended that the diet dry matter (DM) would have to contain a minimum of 35% of total NDF, 25% of forage NDF, and 40% of particles that are larger than 2 mm or have a minimum mean particle size of 2.5 mm. Conversely, the percentage of concentrate in the diet dry matter must remain below 45%, and starch and ruminally degradable starch must be less than 25% and 20% of diet DM, respectively.

The large nutrient demands of high producing animals requires that the proportion of concentrate is increased and fiber is decreased in the diet. These animals typically consume 4% of BW/d of a diet that contains 55% concentrate and 28% NDF with a mean particle size of 2 mm. This situation increases the risk of acidosis and the system of equations that are proposed estimates that average ruminal pH for these animals will be 5.9-6.0. Therefore, it is recommended that feeding management for these animals be consistent from day to day and that supplemental buffers may be beneficial.