Short Communication: Effect of Carbohydrate Fermentation Rate on Estimates of Mass Fermented and Milk Response*

Mary B. Hall

Department of Animal Sciences, University of Florida,
P.O. Box 110910, Gainesville 32611-0910

ABSTRACT

Current prediction equations were used to evaluate the effects of rates of fermentation of fiber or starch in individual feeds on amounts of carbohydrate fermented ruminally and milk yield responses. The small predicted increases in carbohydrate fermented and milk response associated with doubling the rates of fermentation suggest that current prediction equations are relatively insensitive to changes in rate of fermentation. (**Key words:** fermentation rate, prediction equation, carbohydrate, mathematical model)

Abbreviation key: **kd** = rate of fermentation, **kp** = rate of passage.

It seems reasonable to assume that changes in ruminal fermentation rates have the potential to alter animal performance as they change nutrient supply. Increases noted in yields of microbial products in continuous culture (Nocek and Russell, 1988) and in milk production in dairy cattle (Arieli and Adin, 1994) as rates of carbohydrate fermentation increase support this. To quantify change in nutrient supply related to rate of fermentation, the equation $kd/(kd + kp)$, where **kd** = the ruminal rate of fermentation, and **kp** = rate of passage from the rumen, has been used to predict the mass of feed fractions fermented in the rumen (Waldo et al., 1972). The **kd** of carbohydrate fractions has been of particular interest for use in predicting ruminal microbial product yields (Sniffen et al., 1992). Individual **kd** are applied to fractions within feeds, such as sugars, starch, and degradable NDF; the feeds themselves are portions of diets. Typically, a single **kd** is applied to fractions, although **kd** can be altered by pH (Strobel and Russell, 1986) and other dietary components (Heldt et al., 1999). In the current approach to using **kd**, the impact of a change in a single **kd** on the amount of

carbohydrate fermented ruminally should be dependent upon the amount of the carbohydrate to which the rate is applied and on **kp**. The objective of this investigation was to examine the effects of changing **kd** on predictions of mass of carbohydrate fermented ruminally and on supply of energy for milk production using current prediction equations.

Corn silage NDF and starch from ground corn were evaluated at the upper limits of common inclusion rates in lactating cow diets for these feeds that provide substantial amounts of NDF or NSC and that have relatively slow or rapid **kd**. A lactating cow with a DMI of 22.68 kg was chosen for the example because of the potential for consumption of a large mass of NDF or NSC from single feeds. Corn silage containing 45% NDF, 3.6% lignin, and 1.5% CP in NDF (DM basis) comprised 40% of DMI. Ground corn containing 70% starch (DM basis) comprised 20% of DMI. The potentially digestible NDF carbohydrate to which a **kd** was applied was estimated as $NDF - CP \text{ in NDF} - (\text{lignin} \times 2.4)$. Starch was estimated to have a potential digestibility of 100%. Starch from ground corn accounted for 14.00% (3.18 kg) of DMI, and potentially digestible NDF from corn silage provided 13.94% (3.16 kg) of DMI. Three **kd** values were evaluated for each carbohydrate fraction, with the midpoint **kd** being similar to those in the nutritional model CPM Dairy (ver. 1.0, 1998) (Table 1). Mass of NDF or starch fermented ruminally was calculated as $[kd/(kd + kp)] \times (\text{digestible substrate \% of DMI}) \times (\text{DMI, kg})$. Ruminally digested carbohydrate was assumed to be 100% truly digested. The NE_L (Mcal) contents of the digested carbohydrates were calculated using equations 2-8a, 2-10, and 2-11 in the Dairy NRC (2001) and used to estimate the amount of 3.5% fat and 3.0% protein milk that energy from the digested carbohydrate would support (equation 2-16; NRC, 2001).

The predicted maximal differences in amounts of carbohydrate fermented were 316 g of NDF and 204 g of starch when evaluated within **kp** and by 0.02 and 0.10 h^{-1} increments of **kd**, respectively (Table 1). The energy contents of the digested NDF and starch were 0.715 and 0.462 Mcal of NE_L , which could support 1.05 and 0.68 kg of milk, respectively. Even between the greatest

Received November 2, 2003.

Accepted February 23, 2004.

E-mail: hall@animal.ufl.edu.

*This research was supported by the Florida Agricultural Experiment Station and approved for publication as Journal Series No. R-09878.

Table 1. Predicted ruminal extents of fermentation for carbohydrates fermented at different rates of digestion (kd) and passage (kp).¹

	% CHO ¹ fraction fermented	% Diet DM fermented	Digested, g	% CHO ¹ fraction fermented	% Diet DM fermented	Digested, g
Corn silage, NDF; kd, h ⁻¹						
	kp = 0.04 h ⁻¹			kp = 0.06 h ⁻¹		
0.04	50.0	6.97	1581.2	40.0	5.58	1265.0
0.06	60.0	8.37	1897.5	50.0	6.97	1581.2
0.08	66.7	9.30	2108.3	57.1	7.97	1807.1
Ground corn, starch; kd, h ⁻¹						
	kp = 0.04 h ⁻¹			kp = 0.06 h ⁻¹		
0.20	83.3	11.67	2646.0	76.9	10.77	2442.5
0.30	88.2	12.35	2801.6	83.3	11.67	2646.0
0.40	90.9	12.73	2886.5	87.0	12.17	2761.0

¹CHO = Potentially digestible carbohydrate.

and smallest values of kd within a given kp, the maximal difference in NDF digested was 2.39% of diet DM, and 1.40% for starch, the energy contents of which could support 1.80 and 1.06 kg of milk, respectively. The relatively small changes in mass fermented or milk yield noted for a doubling of kd of carbohydrates that supply a significant amount of DMI suggest that current prediction equations are relatively insensitive to changes in kd.

Factors not accounted for with the present use of kd may be the motive forces behind larger changes in animal response as kd changes. Increased milk yield with increased NDF kd may be due in part to increased DMI, increased kp, or reduced ruminal fill, rather than to increased extent of NDF fermentation (Oba and Allen, 1999). Decreased milk yield with potentially increased starch kd as noted by Santos et al. (1997) represents an example of increased processing of grain leading to symptoms of ruminal acidosis and a negative effect on performance. Additionally, the effect of kd may not be comparable among carbohydrates, such as when substitution of sucrose for starch resulted in similar DMI and ruminal pH, but reduced milk yield, despite sucrose being more rapidly degraded than starch (Sannes et al., 2002).

Lactation studies suggest that kd are important to consider in ruminant nutrition. However, kd/(kd + kp) is relatively insensitive to changes in kd within ranges likely for a carbohydrate fraction, and is inadequate in and of itself to accurately describe the effects of changes in kd on animal performance. To make estimates of carbohydrate kd more useful in diet formulation and prediction of nutrient supply, the topic needs improved

concepts of differences among carbohydrates, the roles of interactions among dietary components, ruminal pH, kp, and DMI, and associated calculations for their application.

REFERENCES

- Arieli, A., and G. Adin. 1994. Effect of wheat silage maturity on digestion and milk yield in dairy cows. *J. Dairy Sci.* 77:237–243.
- Heldt, J. S., R. C. Cochran, G. L. Stokka, C. G. Farmer, C. P. Mathis, E. C. Titgemeyer, and T. G. Nagaraja. 1999. Effects of different supplemental sugars and starch fed in combination with degradable intake protein on low-quality forage use by beef steers. *J. Anim. Sci.* 77:2793–2802.
- National Research Council. 2001. Pages 16–17, 19 in *Nutrient Requirements of Dairy Cattle*. 7th rev. ed. National Academy Press, Washington, DC.
- Nocek, J. E., and J. B. Russell. 1988. Protein and energy as an integrated system. Relationship of ruminal protein and carbohydrate availability to microbial synthesis and milk production. *J. Dairy Sci.* 71:2070–2107.
- Oba, M., and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: Effects on dry matter intake and milk yield of dairy cows. *J. Dairy Sci.* 82:589–596.
- Sannes, R. A., M. A. Messman, and D. B. Vagnoni. 2002. Form of rumen-degradable carbohydrate and nitrogen on microbial protein synthesis and protein efficiency of dairy cows. *J. Dairy Sci.* 85:900–908.
- Santos, F. A. P., J. T. Huber, C. B. Theurer, R. S. Swingle, and J. M. Simas. 1997. Response of lactating dairy cows to various densities of sorghum grain. *J. Anim. Sci.* 75:1681–1685.
- Sniffen, C. J., J. D. O'Connor, P. J. Van Soest, D. G. Fox, and J. B. Russell. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *J. Anim. Sci.* 70:3562–3577.
- Strobel, H. J., and J. B. Russell. 1986. Effect of pH and energy spilling on bacterial protein synthesis by carbohydrate-limited cultures of mixed rumen bacteria. *J. Dairy Sci.* 69:2941–2947.
- Waldo, D. R., L. W. Smith, and E. L. Cox. 1972. Model of cellulose disappearance from the rumen. *J. Dairy Sci.* 55:125–129.