The Effect of Chromium Bisglycinate-Nicotinamide Chelate Supplementation on Growth and Carcass Quality in Growing and Finishing Pigs

Jowaman Khajarern, PhD[1]
Sarote Khajarern, PhD[1]
H. DeWayne Ashmead, PhD[2]
Stephen D. Ashmead, MS[2]

[1]*Department of Animal Science*
Khon Kaen University
Khon Kaen, Thailand

[2]*Albion Advanced Nutrition*
Clearfield, Utah

KEY WORDS: pigs, chelated chromium, carcass characteristics, muscling

ABSTRACT

Effects of chromium chelated to glycine and nicotinamide (CrCh) on performance and carcass characteristics of growing and finishing pigs were studied. One hundred eighty Yorkshire × Landrace × Duroc pigs having a mean initial body weight of 30.3 kg were used. Two pens of barrows and 2 pens of gilts were used per treatment, and the study was replicated 4 times. A basal grower and finisher feed was supplemented with 0, 200, or 400 ppb of supplemental CrCh. Pigs received 1 of the 3 grower feeds for 35 days followed by a finisher feed containing the same quantity of CrCh for 51 days. At Day 86, 6 pigs, with a mean body weight of 100.7 kg, were randomly selected from each pen for carcass characteristics evaluation. Because results indicated no differences based on gender, data were pooled for analysis. Average daily gain/feed (g/kg) and feed conversion were not affected by dietary treatment. Dressing percentage trended towards significance in pigs receiving CrCh (P = 0.102; R^2 = 0.603). Longissimus muscle area (LMA) and the percentage of muscling (MUS) were significantly increased (P = 0.002 and P = 0.027, respectively) in pigs receiving CrCh compared with pigs fed the control diet. The difference in MUS between the 2 CrCh-supplemented groups was also significant (P = 0.047). There was a significant difference in 10th rib backfat depth (TRF) between groups receiving CrCh and control (P = 0.019). The TRF tended to decrease as dietary CrCh concentration increased (P = 0.085; R^2 = 0.778). Results of this investigation indicated that either 200 or 400 ppb Cr chelated to glycine and nicotinamide significantly increased LMA and MUS and reduced TRF.

INTRODUCTION

Trivalent chromium (Cr), as part of the glucose tolerance factor, has been reported to enhance glucose utilization and amino acid uptake by insulin sensitive cells.[1] Some researchers, however, have stated seeing little or no benefit resulting from Cr supplementation due to either the amount of Cr required by the animal or the bioavailability of the Cr source provided.[2]

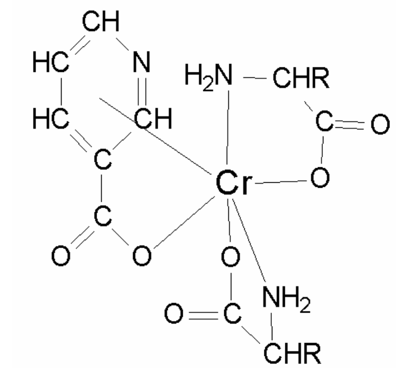
Because inorganic Cr compounds are poorly absorbed,[1] most researchers have focused on Cr complexes such as Cr chelate, Cr picolinate, Cr polynicotinate, and Cr yeast due to their reported greater bioavailabilities.[3,4] Some organic Cr sources have been shown to increase longissimus muscle area (LMA), enhance carcass muscling (MUS), and decrease backfat depth at the 10th rib (TRF) in finishing pigs.[5-8]

With emphasis on Cr bioavailability as the probable key to these carcass improvements, there has been renewed emphasis on developing and testing other bioavailable forms. When Cr+3 was chelated to 2 molecules of glycine and a molecule of nicotinamide (Figure 1), the resultant chelate was reported to have greater bioavailability than many other Cr complexes.[4] Total ^{51}Cr absorption in adult Sprague-Dawley rats was 57.5% for this Cr-bisglycinate-nicotinamide chelate (CrCh), compared to 37.5% for Cr picolinate, 30.0% for Cr polynicotinate, and 30.0% Cr chloride.[9] Chelated Cr results in greater average daily gain (ADG) in cattle compared with either Cr yeast or Cr polynicotinate,[10-12] but it has not been extensively studied in pigs. The purpose of this investigation was to determine if supplement CrCh would enhance growth and/or carcass traits in growing and finishing pigs.

MATERIALS AND METHODS

One hundred eighty crossbred (Yorkshire × Landrace × Duroc) pigs, having a mean initial body weight of 30.3 kg, were used in this 86-day feeding experiment. Equal numbers of barrows and gilts were allotted to 1 of 3 dietary treatments on the basis of gender and body weight in a randomized complete block design. With 15 pigs/pen, each treatment was replicated 4 times, using 2 pens of barrows and gilts in each treatment.

Figure 1. A 2-dimensional depiction of a chromium-nicotinamide-glycine chelate (CrCh). The Cr+3 is bound to 2 molecules of glycine through the amino and carboxyl groups of the amino acids to form coordinate covalent bonds. The nicotinamide is bonded to the Cr+3 through its aromatic π-cloud electrons. The resulting molecule has a Cr-glycine-nicotinamide molar ratio of 1:2:1.



Pens consisted of solid concrete walls measuring 6 m × 8 m with concrete slatted floors. Ambient temperatures ranged from 29°C to 34°C. Consequently, pens were covered with solid sheet metal to provide shade for the animals coupled with a sprinkler system. All pens were open-sided and naturally ventilated.

Grower and finisher basal diets were formulated to generally meet or exceed nutrient requirements of 30- to 100-kg pigs (Table 1).[13] The 3 dietary treatments included the basal diet (Diet 1), the basal diet plus 200 ppb Cr as CrCh (Albion Advanced Nutrition, Clearfield, Utah) (Diet 2), and the basal diet plus 400 ppb Cr as CrCh (Diet 3). The 3 diets were prepared by a local feed company. Analysis of each of the diets was performed by Khon Kaen University prior to being fed.

At approximately 9 AM each day, a premeasured amount of feed was evenly distributed into a steel trough accessible only to those animals in that pen. All feed provided was usually consumed at the time of feeding. Any uneaten feed was removed the next day prior to the pigs being given new feed. The grower feed (Diet 1, Diet 2, or Diet 3) was provided for the first 35 days of

Table 1. Composition of the Basal Diets (as-fed basis).

Item	Grower (30-60 kg)	Finisher (60-100 kg)
Ingredient, % of diet		
Corn	41.92	45.56
Broken rice	20.00	10.00
Rice bran	15.00	30.00
Fish meal (55% CP)	4.00	3.00
Soybean meal (44% CP)	16.00	9.00
Crude rice bran oil	0.50	-
Dicalcium phosphate	1.30	0.90
Limestone	0.30	0.60
DL-Methionine	0.07	-
L-Lysine	0.16	0.22
Salt	0.27	0.30
Vitamin & mineral premix*	0.50	0.50
Calculated composition		
Crude protein, %	16.01	14.13
ME, kcal/kg	3,160.00	3,035.00
Crude fat, %	5.07	7.41
Crude fiber, %	3.22	3.97
Ash, %	5.83	6.53
Calcium, %	0.95	0.83
Total phosphorus, %	0.80	0.94
Available phosphorus, %	0.43	0.42
Lysine, %	0.96	0.85
Methionine + cystine, %	0.63	0.52
Threonine, %	0.63	0.53
Tryptophan, %	0.19	0.14

*Provided the following per kg of premix: vitamin A, 2,500,000 IU; vitamin D3, 400,000 IU; vitamin E, 5,000 IU; vitamin B12, 22 mg; riboflavin, 2.0 g; d-pantothenic acid, 6.0 g; nicotinamide, 9.0 g; choline chloride, 100 g; pyridoxine, 0.25 g; biotin, 5 mg; vitamin K3, 1.25 mg; folic acid, 0.6 mg; Se, 50 µg; Mn, 1.25 g; Fe, 50 g; Cu, 5 g; Co, 100 mg; I, 500 mg; Zn, 55 g.

the study. On Day 36, at which time mean pig weight was approximately 60 kg, all pigs were switched to a finishing feed. The finishing feed was provided for 51 days by which time mean pig weight was approximately 100 kg. Pigs receiving Diet 1 grower feed received Diet 1 finisher feed, pigs receiving Diet 2 grower feed received Diet 2 finisher feed, and pigs receiving Diet 3 grower feed received Diet 3 finisher feed so that each group received the same amount of supplemental Cr in their feed (0, 200 ppb, or 400 ppb) throughout the study. Pigs were allowed ad libitum access to clean water throughout the study via automatic watering nipples.

Pigs were weighed weekly.

At the end of the 86-day feeding period, 6 pigs were randomly selected from each pen and placed in separate pens. Feed was withheld for 12 hours before each was harvested at a local abattoir for carcass evaluation.

The carcass of each pig was identified by its pen number prior to evaluation by a trained veterinarian. Carcass measurements were taken 4 hours after killing, using direct measurements on hot carcasses. Carcass lengths were obtained on the un-ribbed side. Length was measured from the anterior edge of the first rib to the anterior edge of the aitchbone.

The TRF was measured using a metal probe at a point approximately 7.5 cm from the backbone perpendicular to the skin between the 10th and 11th ribs. The LMA was determined by tracing the longissimus muscle at the 10th rib and using the dot grid method to calculate area.[14] Values were adjusted to a common weight of 100.7 kg using the formulas devised by the National Swine Improvement Federation.[15] Percentage muscling in the carcass was calculated according to procedures described by the National Pork Producers Council.[16]

The experimental unit was the pen. Data collected were analyzed using a general linear model analysis of variance and a randomized complete block design. Mean comparison test using Scheffe methods were used to determine treatment differences on variables with significant F-tests.

Additionally, where deemed appropriate, linear regression analysis was performed. A *P*-value less than or equal to 0.05 was considered significant. A *P*-value between 0.05 and 0.10 was considered trending towards significance.

The protocol for this research study was reviewed and approved by Khon Kaen University prior to its commencement.

RESULTS

The results indicated that there was no difference in the pigs based on gender. Consequently, data were pooled for analysis. Unless otherwise indicated, data are reported as the pen means.

Feed consumptions were 2.13-2.15 kg of grower feed/pig/day and 2.33-2.35 kg of finisher feed/pig/day.

The ADG for each group is summarized in Table 2. Regardless of the feeding period, neither ADG nor gain/feed (g/kg) in either the growing or the finishing phase or the combined phases were affected by CrCh supplementation ($P = 0.680$ and $P = 0.874$, respectively, for the combined phases). Numerically, the ADG was greater in both the grower and finisher periods, when feeds were supplemented with 400 ppb CrCh, but the increases were not significant ($P = 0.220$) when compared with Diets 1 and 2.

Carcass lengths of treatment groups were not significantly greater ($P = 0.318$) than control (Table 3). Dressing percentage was almost 1% greater for the group receiving 400 ppb CrCh and trended towards significance ($P = 0.102$; $R^2 = 0.603$).

The LMA was significantly increased ($P = 0.002$) as a result of CrCh supplementation. Average LMA for the pigs fed Diet 1 was 35.5 cm^2, whereas the mean LMA for pigs receiving 200 or 400 ppb Cr as CrCh were 37.6 and 38.1 cm^2, respectively. Compared to the control group, LMA increased by 5.9% for the group receiving 200 ppb CrCh ($P = 0.009$) and 7.3% for the group receiving 400 ppb CrCh ($P = 0.002$).

The mean MUS for Diets 1, 2, and 3 were 50.9%, 52.0%, and 52.5%, respectively. Pigs fed 200 ppb supplemental CrCh increased MUS by 2.2%, whereas MUS in pigs receiving 400 ppb supplemental CrCh increased by 3.1% compared to the control group. There was a significant difference of the MUS from pigs receiving 400 ppb Cr compared to the basal diet ($P = 0.003$). The MUS from pigs receiving Diet 2 was also significantly greater than MUS in pigs receiving the basal diet ($P = 0.029$). There was also a difference in MUS between pigs receiving either 200 or 400 ppb Cr as CrCh ($P = 0.047$).

There was a significant difference between TRF in pigs receiving CrCh compared to control pigs ($P = 0.019$). Backfat appeared to be related to the quantity of CrCh in the diet. The TRF numerically decreased linearly as CrCh concentration increased, suggesting a trend ($P = 0.085$; $R^2 = 0.778$).

Table 2. Effect of CrCh on Average Daily Gain and Gain/Feed (g/kg).*

Response	Diet 1 (Control)	Diet 2 (200 ppb Cr)	Diet 3 (400 ppb Cr)	Pooled SEM
Number of pigs	60	60	60	
Initial mean body weight (kg)	30.28	30.04	30.43	
Final mean body weight (kg)	100.54	100.22	101.47	
Grower period (35 days)				
ADG, g	850	852	857	3.700
Gain/feed, g/kg	397	395	402	0.021
Finisher period (51 days)				
ADG, g	794	792	805	3.663
Gain/feed, g/kg	338	340	342	0.033
Grower-finisher period (86 days)				
ADG, g	817	816	826	3.519
Gain/feed, g/kg	360	361	365	0.028

*Data are means of 4 replications of 15 pigs each.

Table 3. Effect of CrCh on Carcass Characteristics.*

Response	Diet 1 (Control)	Diet 2 (200 ppb Cr)	Diet 3 (400 ppb Cr)	Pooled SEM
Carcass length, cm	86.8	87.5	87.5	0.504
Dressing percentage	74.4	74.4	75.1	0.225
10th rib backfat depth (TRF), mm	11.0[a]	10.5[b]	10.2[b]	0.209
Loin eye area (LMA), cm^2	35.5[a]	37.6[b]	38.1[b]	0.384
Percentage of muscling (MUS)	50.9[c]	52.0[d]	52.5[e]	0.261

*Data are means of 4 replications of 6 pigs each.

[a,b]Means in the same row with different superscripts differ ($P < 0.01$).

[c,d,e]Means in same row with different superscripts differ ($P < 0.05$).

DISCUSSION

In this study, CrCh did not significantly affect ADG or feed conversion. These results are generally in agreement with studies in which Cr picolinate was fed to growing and finishing pigs.[8,17-20]

Lindemann et al[8] reported ADG improved in pigs fed 200 ppb Cr as Cr picolinate when the diets contained 100% of the National Research Council (NRC) recommendations for lysine; however, when the experimental diet was formulated to contain 120% lysine, ADG did not improve. While they initially believed that a Cr-lysine interaction was responsible for improved ADG, it was subsequently determined that the improvement was due to efficiency of the insulin action. In our trial, lysine also exceeded NRC recommendations and ADG in our pigs, like the pigs in the Lindemann et al trials, did not seem to be affected by supplemental Cr. The reason for this should be examined more closely.

Dressing percentage was not affected by CrCh supplementation, which is consistent with previous studies.[17,18,20] When the data were analyzed by least-square means, there was a trend suggesting that 400 ppb Cr influenced the dressing percentage (P = 0.073; R^2 = 0.603).

There was a significant difference between TRF in pigs receiving CrCh and a pigs not fed CrCh (P = 0.019). Backfat appeared to be related to the quantity of CrCh in the diet. The TRF decreased linearly as CrCh concentration increased, suggesting a trend (P = 0.085; R^2 = 0.778). More research needs to be done to determine the optimum level of CrCh.

Both groups of CrCh-supplemented pigs had significantly reduced fat in the loin eye (P = 0.002) and a significant reduction of backfat (P = 0.019) when compared to the control group. Chelated Cr supplementation resulted in a 4.6% (200 ppb Cr) and a 7.3% (400 ppb Cr) decrease in TRF compared to control (P = 0.019). These decreases in backfat appeared to be related to the amount of supplemental CrCh provided (P = 0.085; R^2 = 0.778).

These results are contrary to Lindemann et al,[8] who reported no reduction in TRF in pigs having an initial body weight of 40.9 kg and fed 250 or 500 ppb Cr as Cr picolinate. These investigators, however, reported that weaning pigs weighing 14.5 kg had significantly less TRF than did controls when fed 200 ppb Cr as Cr picolinate.[8] The pigs in the current study were killed at approximately 100 kg body weight, yet only averaged approximately 1 cm TRF. Pigs in the Cr picolinate studies reported by Lindemann et al[8] had TRF from 2 to 3 cm. Previous studies have suggested that CrCh is approximately 50% more bioavailable than Cr picolinate[9] and this may be the reason for lower TRF. Another explanation may be the lower energy density of the finisher diet used in the current trial. While protein and lysine met or exceeded NRC guidelines, estimated metabolizable energy in the finisher feed was approximately 200 kcal/kg less than NRC recommendations.[13] More studies are required before a final determination can be made.

In this study, besides reducing TRF, CrCh supplementation significantly increased both LMA and MUS. These increases appeared to be dose dependent ($P = 0.097$; $R^2 = 0.846$). The more CrCh supplemented, the greater the improvement. The average increases resulting from supplementing with 200 ppb Cr as CrCh were 6.6% for LMA and 2.7% for MUS. These improvements are in agreement with published literature. In one of the trials reported by Lindemann et al,[8] they showed increases of 6.6% and 4.7% for LMA and MUS, respectively, for pigs fed the 200 ppb Cr as Cr picolinate with 120% of the 1988 NRC recommendation for lysine when compared to the corresponding control fed 0 ppb Cr and 120% of the 1988 NRC recommendation for lysine. Kornegay et al[17] reported that feeding 200 ppb Cr as Cr picolinate increased LMA by 6.8% but did not demonstrate any significant improvement in MUS.

Chelating Cr to glycine and nicotinamide creates metabolic dynamics in the pig that are not well understood. It is possible that the observed carcass changes could have been due to chromium's role in carbohydrate, lipid, protein, or nucleic metabolism, or all of the above.[21] Chromium has been shown to be involved in carbohydrate metabolism.[3,19,22] Davis et al[23] postulated that the Cr portion of the glucose tolerance factor results in activation of a membrane enzyme by a low molecular weight Cr binding protein that is released concomitantly with the insulin response to food intake. This may result in an amplification of the insulin signaling mechanism. Abraham et al[24] has shown that Cr is involved with lipid metabolism. Yet other workers have shown a Cr effect on protein and nucleic acid through increasing insulin sensitivity.[1,23,25] Carcass changes also may have resulted from changes in growth hormone concentrations, possibly stimulated by improved Cr bioavailability.[26] More metabolic studies involving CrCh are needed to explain its effect on the pigs in this study.

Most swine diets are composed of ingredients from plant origins, which are generally low in Cr.[27] Feed analysis did not show a measurable amount of Cr in the basal diet suggesting the basal diet may possibly have been moderately deficient in Cr. Supplementing the basal diet with CrCh appeared to provide an alternative means of increasing muscling and reducing fat that was not possible from the feed alone.

Although the NRC has not established a Cr requirement for pigs, 3000 ppm of Cr as Cr oxide or 1000 ppm in the chloride form have been reported as the upper limits for cattle.[28] Providing 200 ppb or 400 ppb of supplemental Cr falls well below these levels and is generally where investigators have focused their studies in pigs. While these amounts, when fed as CrCh, appeared to be sufficient to produce certain significant metabolic responses in growing and finishing pigs, there may be an optimum supplemental level of Cr as CrCh that is as yet unidentified. Additional does response studies with different levels of CrCh are needed to better characterize the total impact of CrCh in growing and finishing pigs.

CONCLUSION

Results from this preliminary investigation demonstrated that supplemental dietary chromium, when provided as a bisglycinate-nicotinamide chelate molecule (CrCh), increases the dressing percentage and significantly improve carcass quality through reducing backfat and increasing longissimus muscle area and the percentage of muscling when fed to growing and finishing pigs.

ACKNOWLEDGEMENTS

Appreciation is expressed to Adsgo Drugs Co., Ltd., in Thailand for its financial support.

REFERENCES

1. Anderson RA: Chromium. In: Mertz W, ed. *Trace Elements in Human and Animal Nutrition*. 5th edition. San Diego, Calif; Academic Press; 1987:225.
2. Oberleas D, Li YC, Stoecker BJ, Henley SA, KeimKS, Smith JC Jr: The role of chromium transit through the gastrointestinal tract. *Nutr Res* 1990;10:1189-1194.
3. Mertz W: Chromium in human nutrition: a review. *J Nutr* 1993;123:626-633.
4. Mowat DN: *Organic Chromium in Animal Nutrition*. Guelph, Ontario, Canada: Chromium Books; 1997.
5. Mooney KW, Cromwell GL: Effects of dietary chromium picolinate supplementation on growth, carcass characteristics, and accretion rates of carcass tissues in growing-finishing swine. *J Anim Sci* 1995;73:3351-3357.
6. Page TG, Southern LL, Ward TL, Thompson DL Jr: Effect of chromium picolinate on growth and serum and carcass traits of growing-finishing pigs. *J Anim Sci* 1993;71:656-662.
7. Smith JW II, Owen KQ, Nelssen JL, et al: The effects of dietary carnitine, betaine and chromium nicotinate supplementation on growth and carcass characteristics in growing-finishing pigs [abstract]. *J Anim Sci* 1994;77(suppl 1):274.
8. Lindemann MD, Wood CM, Harper AF, Kornegay ET, Anderson RA. Dietary chromium picolinate additions improve gain:feed and carcass characteristics in growing-finishing pigs and increase litter size in reproducing sows. *J Anim Sci* 1995;73:457-465.
9. Ashmead H, Ashmead S: Albion research: Past, present and future. Proceedings of the Albion Laboratories, Inc. International Conference on Human Nutrition. January 21-22 1995, Salt Lake City, Utah. 117:1-8.
10. Mowat DN, Yang WZ: Sources of chromium for stressed feeder calves. In: *Beef Research Update*. University of Guelph, Ontario, Canada:1991:1.
11. Mowat DN, Chang X, Yang WZ: Chelated chromium for stressed feeder calves. *Can J Anim Sci* 1993;73:49-55.
12. Chang X, Mowat DN: Supplemental chromium for stressed and growing feeder calves. *J Anim Sci* 1992;70:559-565.
13. National Research Council (NRC): *Nutrient Requirements of Swine*. 10th edition. Washington, DC: National Academy Press; 1998.
14. Akridge JT, Borsen BW, Whipker LD, Forest JC, Kuei CW, Schinckel AP: Evaluation of alternative techniques to determine pork carcass value. *J Anim Sci* 1992;70:18-28.
15. National Swine Improvement Federation (NSIF): *Guidelines for Uniform Swine Improvement Programs*. Washington, DC: NSIF; 1988.
16. National Pork Producers Council (NPPC): *Procedures to Evaluate Market Hogs*. 3rd edition. Des Moines, Iowa: NPPC; 1991.
17. Kornegay ET, Wang Z, Wood CM, Lindemann MD: Supplemental chromium picolinate influences nitrogen balance, dry matter digestibility, and carcass traits in growing-finishing pigs. *J Anim Sci* 1997;75:1319-1323.
18. Ward TL, Southern LL, Bidner TD: Interactive effects of dietary chromium tripicolinate and crude protein level in growing-finishing pigs provided inadequate and adequate pen space. *J Anim Sci* 1997;75:1001-1008.
19. Amoikon EK, Fernandez JM, Southern LL, Thompson DL Jr, Ward TL, Olcott BM: Effect of chromium tripicolinate on growth, glucose tolerance, insulin sensitivity, plasma metabolites, and growth hormone in pigs. *J Anim Sci* 1995;73:1123-1130.
20. Boleman SL, Boleman SJ, Bidner TD, et al: Effect of chromium picolinate on growth, body composition, and tissue accretion in pigs. *J Anim Sci* 1995;73:2033-2042.
21. Nielsen FH: Chromium. In: Shils ME, Olson JA, Shike M, eds. *Modern Nutrition in Health and Disease*. 8th edition. Philadelphia, Pa: Lea & Febiger; 1994:264.
22. Evock-Clover CM, Polansky MM, Anderson RA, Steele NC: Dietary chromium supplementation with or without somatotropin treatment alters serum hormone and metabolites in growing-pigs without affecting growth performances. *J Nutr* 1993;123:1504-1512.
23. Davis CM, Sumrall H, Vincent JB: A biologically active form of chromium may activate a membrane phosphotyrosine phosphate (PTP). *Biochemistry* 1996;35:12963-12969.
24. Abraham AS, Brooks BA, Eylath U: Chromium and cholesterol-induced atherosclerosis in rabbits. *Ann Nutr Metab* 1991;35:203-207.
25. Ohba H, Suketa Y, Okada S: Enhancement of in vitro ribonucleic acid synthesis on chromium (III)-bound chromatin. *J Inorg Biochem* 1986;27:179-189.
26. Okada S, Suzuki M, Ohba H: Enhancement of ribonucleic acid synthesis by chromium (III) in mouse liver. *J Inorg Biochem* 1983;19:95-103.
27. Giri J, Usha K, Sunitha T: Evaluation of the selenium and chromium content of plant foods. *Plant Foods Hum Nutr* 1990;40-49.
28. National Research Council (NRC): *Nutrient Requirements of Dairy Cattle*. 7th edition. Washington, DC: National Academy Press; 2001.