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Protein Requirements for Finishing Beef Cattle

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Summary

- Reviewed research indicates that feedlots currently feed protein concentrations that vary from 12.5 to 14% CP (DM basis).
- Both reviewed and current research at the University of Arizona has indicated that optimal protein concentrations in feedlot diets fall somewhere between 12.0 to 13.0%.
- Research suggests that urea can be supplemented at up to 1.5% of dietary DM and utilized as 100% of the supplemental CP without any detrimental effects.
- Little research has been reported on the effects of gender and genotype on protein requirements.
- A study at the University of Arizona showed protein requirements to be similar between steers and heifers with the exception that heifers were most efficient at 14.0% CP while steers were most efficient at 12.5 % CP.
- The goal of this paper is to review previous studies and utilize current findings to suggest future research needs related to protein requirements in finishing cattle.

Introduction

Considering today's growing environmental concerns and ever increasing feed costs, feeding appropriate CP levels is of the utmost importance in the feedlot industry. Overfeeding CP may be detrimental to the environment by increasing nitrogen excretion and consequently increasing the evolution of NH_3 into the environment (Klemesrud et al., 2000). However, underfeeding CP may result in decreased ADG, ADFI, G:F and carcass quality as suggested by Galyean (1996). Fox and Black (1984) indicated that prediction of body composition in cattle is necessary to predict net nutrient requirements, and speculated that weight, rate of gain, frame size, breed type, sex, use of growth stimulants, special dietary effects and the nutritional management system, all affect body composition. Dicostanzo and Zehnder (1999) speculated that greater protein requirements are expected as genetic manipulation of cattle led to the production of leaner, later maturing cattle types. Another factor contributing to increased protein needs is advances in feed additives, such as melengesterol acetate (MGA) and ractopamine, and anabolic implants, all of which increase lean tissue accretion. However, animals fed as natural beef, lacking these implants and feed additives, likely could be fed reduced protein concentrations compared to their implanted and supplemented contemporaries. Schingoethe et al. (1988) reported that providing high-energy concentrations, in any phase, accentuates fat deposition, especially for animals with a limited capacity for protein growth, as most animals will consume sufficient nutrients to allow extensive fat deposition unless vast redirection toward protein deposition is provided. Consequently, feeding less than the required amount of CP, to normal fed feedlot calves, consuming a high-energy diet, could limit returns on improved genetics, implant strategies, and feed additives; whereas, overfeeding CP to natural fed beef, might, not only be wasteful and detrimental to the environment, but could also reduce premiums gained by selling in a niche market.

Even so, practical diets for growing and finishing cattle typically are formulated on a CP basis, with little or no consideration of ruminal N transactions and/or the protein/ amino acid requirements of the host ruminant (Galyean, 1996). From 1995 to 2000 there has been a substantial swing in the numbers of steers and heifers in feedlots throughout the United States, which amounts to a 5% decline in steer numbers, and a 5% increase in heifer numbers (USDA, 2000). In the southwest, many of these heifers are coming out of Mexico and are required, by federal law, to be ovariectomized upon entry into the United States. This swing in numbers and cattle importation laws has brought about an increasing need to re-evaluate the protein requirement differences in feedlot cattle. This paper reviews previous studies, highlights current findings, and proposes new research pertaining to protein requirement questions for finishing cattle. Several research projects have recently been planned or are in progress to answer some of these questions. Results from some of these projects conducted at the University of Arizona will be presented in this paper.

Current Recommendations

Galyean (1996), in interviewing six feedlot nutritionist, noted that, overall, the formulated values for percentage CP (DM basis) in finishing diets ranged from 12.5 to 14.4%. Shain et al. (1994) suggested the protein requirement in finishing steers to be 12% due to an overfeeding of UIP. Gleghorn et al. (2004), suggested the optimal CP requirement for finishing steers fed a steam-flaked corn based diet to be approximately 13%, as increasing CP concentration to 14.5% did not improve any performance or carcass merit parameters. Likewise, we found, in a recent trial at the University of Arizona (**Table 1**; unpublished data), that increasing CP concentrations beyond 12.5% did not improve feedlot performance or carcass characteristics. Gleghorn et al. (2004) also found that increasing CP to 14.5% increased serum urea nitrogen (SUN) concentrations compared to both 11.5 and 13.0% diets, suggesting that feeding greater than 13% CP exceeded the requirement of finishing cattle. Therefore, evidence from these studies strongly suggests that finishing cattle have a protein requirement of approximately 12.0 to 13.0 % and feeding any concentration greater than that seems to have no advantageous effects.

Galyean (1996) also indicated that in today's feedlot diets, a considerable portion of the total CP, beyond that supplied by dietary ingredients, is derived from urea, ranging from 0.5 to 1.5% of the diet. This is made possible by the ruminal microflora's ability to convert large amounts of non-protein nitrogen (NPN), such as urea, to true protein. Rumen microbes do this by first hydrolyzing urea to CO_2 and NH_3. The NH_3 then has one of three fates: it is either incorporated into microbial protein, absorbed across the ruminal wall (rate dependent on the rumen:blood NH_3 concentration gradient and rumen pH), or flushed to the omasum (Owens and Zinn, 1988). Gleghorn et al. (2004) indicated that increasing the proportion of urea supplemented CP from 0 to 100% increased carcass adjusted ADG, G:F, carcass adjusted G:F, HCW, and LM area. Zinn et al. (2003) reported that urea is an effective ruminal alkalizing agent in the first hour post-feeding. This is likely due to the H^+ scavenging ability of NH_3 in the rumen as it is rapidly converted to NH_4^+. This rise in pH also causes a more rapid absorption of NH_3 across the rumen wall (Owens and Zinn, 1988). It was therefore speculated that feeding greater amounts of urea in the diet could be efficacious in further fighting systemic acidosis, as NH_3 is also utilized as an H^+ scavenger in the kidney to maintain systemic pH homeostasis (Guyton and Hall, 2000). However, Cole et al. (2003) reported that dietary CP did not significantly affect acid-base balance. Similarly, we recently reported (Bailey et al., 2004; **Table 2**) that increasing dietary urea from 0 to 1.5% of an iso-nitrogenous diet does not affect blood pH, blood gas profile, SUN, or urine pH. However, the diets in our study were below reported DIP requirements and less than the reported range of CP fed by the feedlots interviewed by Galyean (1996). Therefore, we concluded that further research was necessary to determine if urea does not have any real systemic buffering capability.

Gender and Protein Requirements

In examining gender related differences in protein requirements, or at least in deciding if there is a need to re-examine protein requirements in relation to gender, it is important to look at advances that have been made in the swine industry. Unruh et al., (1996) indicated that when gilts and barrows were fed identical diets, to similar weights, gilts had a greater percentage of lean than barrows, and increased dietary lysine enhanced cutability in high lean growth gilts fed to 104 kg but not 127 kg, while additional lysine produced fatter carcasses in barrows finished to both 104 and 127 kg. Friesen et al. (1994) reported that within genotype, gender differences result in alterations in growth performance, protein accretion, and lysine requirements in growing-finishing swine. Additionally, Cromwell et al. (1993) indicated that gilts require higher levels of dietary protein (lysine) to maximize rate and efficiency of gain and carcass muscle than do barrows. They further speculated that penning barrows and gilts separately and feeding diets that more closely met their nutrient requirements might provide an economic advantage to producers.

Beef cattle research has indicated that bulls deposit more lean tissue than steers (Vanderwert et al., 1985; Anderson et al., 1986), which deposit a greater amount of lean tissue than heifers (Berg et al., 1979; Fox and Black, 1984). Crouse et al. (1985) indicated that intact males had a greater ADG and feed intake compared to castrates and they were also larger and more muscular than castrated males at a given rib fat percentage. Field (1971), reported that intact males had a 2.6% average advantage in cutability compared to castrates, while Crouse et al. (1985) showed no advantage in leanness of castrates compared to intact males. However, Anderson et al. (1986) indicated that bulls consume less feed per unit of body weight or metabolic body size than steers, but excelled steers in the proportion of dry matter gained as protein. Data for differences in heifer growth and composition after ovariectomy is also variable. Dinusson et al. (1950) and Horstman et al. (1982) reported that ovariectomy had an adverse influence on rate and efficiency of growth. Conversely, Ray et al. (1969) showed that, in the feedlot, steers outperformed intact heifers, which, in turn outperformed ovariectomized heifers. However, Klindt and Crouse (1990) and Hamernik et al. (1985) indicated that ovariectomy did not influence ADG compared to intact heifers, and Field et al. (1996) indicated that there was no difference in total gain when ovariectomized heifers were compared to intact heifers. Klindt and Crouse (1990) also indicated that ovariectomized heifers were not as lean as intact heifers and Field et al. (1996) reported that intact virgin heifers had greater LM area and less KPH compared to ovariectomized heifers, but they reported no differences in fat depth. It is also notable that Garber et al. (1990) reported that ovariectomized heifers exhibited a fourfold greater response to implantation than intact heifers. These data suggest, that, on a body weight basis, bulls utilize protein more efficiently than steers, and therefore, when compared to steers, may not have an increased CP concentration requirement. Accordingly, although no research has examined differences in the efficiency of N utilization for steers, compared to either intact, or ovariectomized heifers, one could speculate that similar results may be found, especially in intact compared to ovariectomized heifers.

In a recent experiment completed at the University of Arizona (unpublished data; **Table 1**) we found that, although heifers consumed less and gained less than steers (P <0.01) and had lighter HCW ($P < 0.01$), they were leaner in that they had less KPH ($P = 0.08$), tended to have less 12th rib backfat (BF; $P = 0.15$) and had a lower numerical yield grade ($P < 0.01$). The reason for the lower numerical yield grade advantage in heifers was likely due to steers having no advantage in LM area, which prevented them from overcoming their yield grade formula disadvantages in KPH, HCW, and BF. It is also notable that we observed a gender x protein level interaction (P=0.01) with respect to G:F as indicated by the following least square interaction means: steers (11.0, 0.205; 12.5, 0.217; 14.0, 0.205) heifers (11.0, 0.203; 12.5, 0.205; 14.0, 0.216). Steers were most efficient at 12.5% CP, while heifers were most efficient at 14.0% CP. This could be a reflection of the heifers' overall advantage in leanness.

It should also be noted that the lack of increase in performance from the 12.5 to the 14% diets could have been a reflection of genotype of the cattle. The cattle we used were predominantly English-based breeds and were small to medium-framed; therefore, they may have lower CP requirements than medium to large-framed, Continental type cattle, that are likely more representative of the majority of cattle on feed in the United States. Coleman et al., (1993) indicated that Charolais steers had a greater lean to fat ratio, a greater LM area and less backfat compared to Angus steers. Crouse et al. (1985) reported that Simmental steers, when compared to Angus steers, weighed more and had a greater HCW and greater LM area. Swine research proposes that when developing effective swine finishing strategies, for individual groups of growing-finishing pigs, it is important that the pig's lean growth potential be considered (Friesen et al., 1994). Chen et al., (1995) indicated that pigs with a greater genetic potential for lean growth reached peak performance at higher levels of CP than did pigs with less genetic potential for lean growth. They also reported that overfeeding, as well as underfeeding, dietary protein decreased daily gain and feed efficiency. Other swine research (Unruh et al., 1996) suggests that segregation of pigs by genotype and sex could be used to optimize live performance and carcass traits. Applying these results to reported results from cattle research makes a strong argument for further evaluating CP requirements in beef cattle based on genotype.

In conclusion, previous research has indicated CP requirements for finishing cattle to fall between 12 and 13%, and that providing supplemental protein solely as urea, as opposed to natural sources such as cottonseed or soybean meal, at up to 1.5% of the dietary DM, improves feedlot performance and carcass characteristics. However, reviewed research and research conducted at the University of Arizona has shown that while urea may be an effective ruminal alkalizing agent it does not appear to be efficacious as a systemic buffer. It is also notable that reviewed research concerning CP requirements does not account for gender or genotype. Preliminary research, at the University of Arizona, has shown heifers to be more feed efficient when fed greater amounts of CP (up to 14.0%); however, feeding protein amounts greater than 12.5% did not improve any other performance or carcass parameters for finishing cattle in this study. Even so, this could be because the cattle utilized were smaller-framed, English type, cattle, which may not have as high of a CP requirement as larger-framed, Continental type, cattle. More research is warranted to grasp differences in protein requirements based on gender and genotype.

References

Anderson, P.T., D.R. Hawkins, W.G. Bergen, and R.A. Merkel. 1986. Dry matter intake, composition of gain and other measures of Simmental bulls and steers fed to two endpoints. J. Anim. Sci. 63(Suppl. 1):99 (Abstr).

Bailey, C.R., G.C. Duff, R.C. Cheatham, S.R. Sanders, T.W. Whitney, O.B. Mendivil, and J.L. Treichel. 2004. Dietary urea concentration and acid-base balance in feedlot steers fed a high concentrate steam-flaked corn based diet. Can. J. Anim. Sci. 84:(4) 741 – 743.

Berg, R.T., S.D.M Jones, M.A. Price, R. Fukuhara, R.M. Butterfield, and R.T. Hardin. 1979. Patterns of carcass fat deposition in heifers, steers and bulls. Can. J. Anim. Sci. 59:359 – 366.

Chen, H.Y., P.S. Miller, A.J. Lewis, C.K. Wolverton, and W.W. Stroup. 1995. Changes in plasma urea concentration can be used to determine protein requirements of two populations of pigs with different protein accretion rates. J. Anim. Sci., 73:2631 – 2639.

Cole, N. A., L.W. Greene, F.T. McCollum, T. Montgomery, and K. McBride. 2003. Influence of oscillating dietary crude protein concentration on performance, acid-base balance, and nitrogen excretion of steers. J. Anim. Sci. 81:2660 – 2668.

Coleman, S.W., B.C., Evans, and J.J. Guenther. 1993. Body and carcass composition of Angus and Charolais steers as affected by age and nutrition. J. Anim. Sci. 71:86 – 95.

Cromwell, G.L., T.R. Cline, J.D. Crenshaw, T.D. Crenshaw, R.C. Ewan, C.R. Hamilton, A.J. Lewis, D.C. Mahan, E.R. Miller, J.E. Pettigrew, L.F. Tribble, and T.L. Veum. 1993. The dietary protein and (or) lysine requirements of barrows and gilts. J. Anim. Sci. 71:1510 – 1519.

Crouse, J.D., C.L. Ferrell, and L.V. Cundiff. 1985. Effects of sex condition, genotype and diet on bovine growth and carcass characteristics. J. Anim. Sci. 60: 1219 – 1227.

Dicostanzo, A.P. and C.M. Zehnder. 1999. Estimation of protein requirements of feedlot steers. Prof. Anim. Sci. 15:116 – 123.

Dinusson, W.E., F.N. Andrews, and W.M. Beeson. 1950. The effects of stilbestrol, testosterone, thyroid alteration, and spaying on the growth and fattening of beef heifers. J. Anim. Sci. 9:321 – 330.

Field, R.A. 1971. Effect of castration on meat quality and quantity. J. Anim. Sci. 32: 849 – 858.

Field, R., R. McCormick, V. Balasubramanian, D. Sanson, J. Wise, D. Hixson, M. Riley, and W. Russell. 1996. Growth, carcass, and tenderness characteristics of virgin, spayed, and single-calf heifers. J. Anim. Sci. 74:2178 – 2186.

Fox, D.G. and J.R. Black. 1984. A system for predicting body composition and performance of growing cattle. J. Anim. Sci. 58: 725 –739.

Friesen, K.G., J.L. Nelssen, J.A. Unruh, R.D. Goodband, and M.D. Tokach. 1994. Effects of the interrelationship between genotype, sex, and dietary lysine on growth performance, and carcass composition in finishing pigs fed to either 104 or 127 kilograms. J. Anim. Sci. 72:946 – 954.

Galyean, M.L. 1996. Protein levels in beef cattle finishing diets: Industry application, university research, and systems results. J. Anim. Sci. 74:2860 – 2870.

Garber, M. J., R.A. Roeder, J.J. Combs, L. Eldridge, J.C. Miller, D.D. Hinman, and J.J Ney. 1990. Efficacy of vaginal spaying and anabolic implants on growth and carcass characteristics in beef heifers. J. Anim. Sci. 68: 1469 – 1475.

Gleghorn, J.F., N.A. Elam, M.L. Galyean, G.C. Duff, N.A. Cole, and J.D. Rivera. 2004. Effects of dietary crude protein level and degradability on performance and carcass characteristics of growing – finishing beef steers. J. Anim. Sci. 82:2705 – 2717.

Guyton, A. C. and J. E. Hall (Eds.). 2000. Textbook of Medical Physiology. W. B. Saunders Company. Philadelphia, PA.

Hamernik, D.L., J.R. Males, C.T. Gaskins, and J.J. Reeves. 1985. Feedlot performance of hysterectomized and ovariectomized heifers. J. Anim. Sci. 60:358 – 362.

Horstman, L.A., C.J. Callahan, R.L. Morter, and J.E. Amstutz. 1982. Ovariectomy as a means of abortion and control of estrus in feedlot heifers. Theriogenology 17:273 – 292.

Klemesrud, M.J., T.J. Klopfenstein, R.A. Stock, A.J. Lewis, and D.W. Herold. 2000. Effect of dietary concentration of metabolizable lysine on finishing cattle performance. J. Anim. Sci. 78:1060 – 1066.

Klindt, J. and J.D. Crouse. 1990. Effect of ovariectomy and ovariectomy with ovarian auto transplantation on feedlot performance and carcass characteristics of heifers. J. Anim. Sci. 68:3481 – 3487.

Owens, F. N. and R.A. Zinn. 1988. Protein metabolism of ruminant animals. Pages 229 – 231 in The Ruminant Animal: Digestive Physiology and Nutrition. D.C. Church ed. Prentice-Hall, Inc. Englewood Cliffs, NJ 07632.

Ray, D.E., W.H. Hale, and J.A. Marchello. 1969. Influence of season, sex and hormonal stimulants on feedlot performance of beef cattle. J. Anim. Sci. 29: 490 – 495.

Schingoethe, D.J., F.M. Byers, and G.T. Schelling. 1988. Nutrient needs during critical periods of the life cycle. Pages 421 – 447 in The Ruminant Animal: Digestive Physiology and Nutrition. D.C. Church ed. Prentice-Hall, Inc. Englewood Cliffs, NJ 07632.

Shain, D.H., R.A. Stock, T.J. Klopfenstein, and R.P. Huffman. 1994. Level of rumen degradable nitrogen in finishing cattle diets. J. Anim. Sci. 72(Suppl. 1): 923 (abstr.).

Unruh, J.A., K.G. Friesen, S.R. Stuewe, B.L. Dunn, J.L. Nelssen, R.D. Goodband, and M.D. Tokach. 1996. The influence of genotype, sex, and dietary lysing on pork subprimal cut yields and carcass quality of pigs fed to either 104 or 127 kilograms. J. Anim. Sci., 74:1274 – 1283.

USDA. 2000. Changes in the U.S. feedlot industry: 1994 – 1999. USDA:APHIS:VS, CEAH, National animal health monitoring system. Fort Collins, CO. #N327.0800.

Vanderwert, W., L.L. Berger, F.K. McKeith, A.M. Baker, H.W. Gonyou and P.J. Bechtel. 1985. Influence of Zeranol implants on growth, behavior and carcass traits in Angus and Limousin bulls and steers. J. Anim. Sci. 61:310 – 319.

Zinn, R.A., R. Barrajas, M. Montano, and R.A. Ware. 2003. Influence of dietary urea level on digestive function and growth performance of cattle fed steam-flaked barely-based diets. J. Anim. Sci. 81:2383-2389.

Table1: Effect of dietary protein concentration on growth performance parameters and carcass characteristics of steers and heifers finished on a high concentrate diet.

	Level				*P* Value		Gender			
Item	11.0	12.5	14.0	SEM[a]	L[b]	Q[b]	Steers	Heifers	*P* Value	SEM[a]
Initial wt., kg	322	339	334	4.60	0.06	0.06	350	313	<0.01	3.68
Final wt., kg	489	517	504	6.40	0.08	0.01	532	474	<0.01	5.11
DMI, kg/d	10.0	10.8	10.2	0.24	0.42	0.02	10.9	9.9	<0.01	0.20
ADG, kg	1.9	2.1	2.0	0.05	0.53	0.05	2.1	1.9	<0.01	0.04
G:F[c]	0.19	0.19	0.19	0.01	0.94	0.94	0.20	0.19	0.13	0.01
HCW, kg	289	304	302	3.95	0.02	0.08	316	281	<0.01	3.18
Dressing %	59.2	58.9	59.9	0.50	0.26	0.29	59.4	59.3	0.91	0.40
KPH, %	2.21	2.30	2.29	0.11	0.69	0.58	2.38	2.16	0.08	0.09
Backfat, cm	1.08	1.24	1.24	0.05	0.04	0.26	1.23	1.14	0.15	0.04
LM area, cm^2	75.77	75.65	76.90	1.37	0.56	0.69	77.04	75.18	0.25	1.14
Marbling score	502	498	503	12.46	0.92	0.74	517	484	0.02	10.23
Yield grade	2.68	2.97	2.89	0.09	0.09	0.09	3.01	2.69	0.07	<0.01

[a] Standard Error of the mean (Most conservative estimate; n=18)

[b] L = linear, Q = quadratic

[c] Level x gender interaction $P < 0.05$ (See text for least square interaction means

Table 2: Arterial blood acid-base profile and venous serum urea N (SUN) of steers fed four different isonitrogenous diets containing 0, 0.5, 1.0, or 1.5% urea (DM basis)

	Dietary Urea						
Item	0	0.5	1.0	1.5	SEM[1]	Linear	Quadratic
ADFI, kg	9.31	9.56	9.55	9.99	0.24	0.57	0.71
Arterial pH	7.51	7.53	7.51	7.55	0.02	0.26	0.64
pCO_2, mm Hg	31.01	32.74	33.52	29.20	2.66	0.68	0.24
pO_2, mm Hg	102.45	102.62	94.68	110.78	8.33	0.51	0.18
SUN, mg/dL	14.67	12.42	12.08	12.66	1.75	0.23	0.23

[1] Standard error of the mean (Most conservative estimate; n = 4)

Adapted from (Bailey et al., 2004)