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EFFECTS OF UREA AS A SOURCE OF EXTRA DIETARY NITROGEN ON GROWTH PERFORMANCE AND CARCASS TRAITS OF FINISHER PIGS

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ABSTRACT

Forty-two crossbred pigs weighing 54.2 ± 5.5 kg were used to evaluate the value of urea as a source of extra nitrogen (**N**) to enhance carcass leanness of finisher pigs. Three soybean meal (**SBM**) diets were formulated to contain 0.60 and 13.2% (**Low**), 0.73 and 15.5% (**Med**) or 0.85 and 16.7% (**High**) lysine and crude protein (**CP**), respectively. Two urea diets were formulated to be iso-nitrogenous (**Iso-N**) to the Med and High SBM diets. Two additional urea diets were formulated to be iso-lysinic (**Iso-Lys**) to the Med and High SBM diets by incorporating crystalline amino acids. The indispensable amino acid contents were at least 20.8 and 41.7% above the current NRC requirements for the Med and High Iso-Lys diets, respectively. To ensure an adequate supply of CP from common feed ingredients for pigs, corn and SBM contributed 13.2% CP to four urea diets, and urea supplied additional CP equivalent. Pigs were housed individually, and allowed ad libitum access to feed. All pigs were slaughtered at an average weight of 103.2 ± 4.5 kg. Pigs fed the Low SBM diet tended to grow faster ($P = 0.09$) than those fed other diets (1.09 vs 1.02 kg/day). However, the average backfat (**BF**; 36.4 vs 32.1 mm; $P < 0.05$) and 10th rib BF (33.1 vs 28.9 mm; $P = 0.10$) were higher, and carcass specific gravity (1.046 vs 1.041; $P < 0.05$) and proportion of lean (47.6 vs 44.7%; $P = 0.08$) were lower in pigs fed the Low diet than those fed the Med and High diets, indicating that a higher weight gain was achieved by the increased rate of fat accretion. The results indicated that the carcass quality was improved by increasing lysine and(or) N levels from low to medium regardless of the source [SBM or urea and(or) amino acids]. In addition, simply incorporating urea to increase dietary N (Iso-N) from low to medium and amino acid supplementation of urea diets (Iso-Lys) were equally effective in enhancing the carcass quality of pigs, indicating that overall utilization of diets was improved by the inclusion of urea. There was, however, no improvement in the carcass quality of finisher pigs with further increases in dietary lysine and(or) N levels from medium to high.

KEY WORDS: Finisher Pigs, Extra Dietary Nitrogen, Urea, Carcass Traits

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INTRODUCTION

As the amino acid or nitrogen (**N**) content of diets increases, there is a concomitant improvement in leanness of pigs (e.g., 1,2). Numerous factors are responsible for this effect, but essentially pigs fed a high-N diet have less energy available for excess fat accretion, thus improving carcass leanness. Providing extra dietary N, therefore, might be a viable means to enhance the carcass quality of finisher pigs. Increasing dietary N can be a costly method to enhance carcass leanness of pigs, but the quantity of extra dietary N may be more important than the quality of N sources (3). This contention implies that inexpensive N supplements can be used for this purpose.

Chiba et al. (4) reported that extra dietary N (i.e., above the optimum level) provided by soybean meal or hydrolyzed feather meal was equally effective in enhancing the carcass quality of finisher pigs. In addition, the improved carcass quality in response to the increase in dietary N was independent of method of incorporating feather meal in diets (i.e., iso-N or iso-lysinic). These results may indicate that it is possible to use low quality N supplements as a source of extra dietary N for improving carcass leanness. The research described herein was designed to investigate the potential value of urea as a source of extra N to enhance carcass leanness, and to determine the effect of amino acid supplementation of urea diets on the growth performance and leanness of finisher pigs.

EXPERIMENTAL PROCEDURES

Animals and Facility. Twenty-one gilts and 21 castrated males (Landrace x Yorkshire x Duroc) were selected based on the weight and housed individually in pens with solid concrete floors in open-front buildings. At an average weight of 54.2 $\pm$ 5.5 kg, backfat thickness (**BF**) was measured with an ultrasound instrument (Renco Corp., Minneapolis, MN) 4 to 5 cm from the midline at the third rib, last rib and last lumbar vertebra. Pigs were randomly assigned within sex and weight group to seven dietary treatments with three gilts and three castrated males per diet. All pigs were slaughtered at an average weight of 103.2 $\pm$ 4.5 kg to assess carcass traits. The experiment was initiated in September and terminated in October. Pigs were allowed *ad libitum* access to feed and water. Pig weight and feed consumption data were recorded once every two weeks. Near the end of the experiment, data were collected more frequently according to the slaughter schedule.

Experimental Diets. Based on the results of previous experiments (5), a diet containing 0.73% lysine and 15.0% crude protein (**CP**) was selected as the basis for the present experiment. To assess the value of soybean meal (**SBM**) and urea as a source of extra dietary N, and to ascertain whether a possible response in leanness of pigs is due to increased N *per se* or to increased amino acid contents, three series of diets were formulated (Table 1). Three SBM diets were formulated to contain 0.60 and 13.2% (**Low**), 0.73 and 15.0% (**Med**) or 0.85 and 16.7% (**High**) lysine and CP, respectively. Dietary lysine levels were 20.8 and 41.7% higher than the current NRC (6) recommendation for the Med and High SBM diets, respectively. Two urea diets were formulated to be iso-nitrogenous (**Iso-N**) to the Med and High SBM diets. Two additional urea diets were formulated to be iso-lysinic (**Iso-Lys**) to the Med and High SBM diets by adding crystalline amino acids to the Iso-N diet.

To ensure an adequate supply of CP from common feed ingredients for pigs, corn and SBM contributed 13.2% CP to all urea diets, and urea provided the additional CP equivalent. Urea contributed 11.7 and 20.9% of total CP equivalent, respectively, to the Med and High Iso-N or Iso-Lys diets. The content of all indispensable amino acid was at least 20.8 and 41.7% above the NRC (6) recommendations for the Med and High Iso-Lys diets, respectively, and this was achieved by supplementing with appropriate amounts of L-lysine·HCl and L-threonine. The proportions of

indispensable amino acids relative to lysine were above the balance suggested by the NRC (6), and all diets were formulated to meet or exceed nutrient requirements for finisher pigs established by the NRC (6). Feed samples were analyzed for CP by the Kjeldahl method (7), and for amino acids by the method described previously (8).

The medium was considered to be the optimum level of dietary lysine or CP for pigs used in this research. A fundamental assumption of the design was that providing extra dietary lysine or CP (i.e., above the optimum level) would have no effect on the rate of protein accretion, but it would reduce the rate of fat accretion, thus improving leanness of finisher pigs.

TABLE 1
Composition of Experimental Diets*

				Urea diets			
	SBM diets			Iso-N		Iso-Lys	
Item	Low	Med	High	Med	High	Med	High
Ingredients, %:							
Corn	84.62	80.33	76.04	83.20	81.81	83.04	81.45
SBM (48% CP)	12.45	16.80	21.15	12.65	12.84	12.67	12.87
Urea	-	-	-	0.62	1.24	0.62	1.24
L-lysine·HCl	-	-	-	-	-	0.15	0.31
L-threonine	-	-	-	-	-	-	0.03
Dried fat#	-	-	-	0.58	1.16	0.58	1.16
Dicalcium phosphate	1.53	1.45	1.36	1.55	1.56	1.55	1.56
Limestone	0.80	0.82	0.85	0.80	0.79	0.79	0.78
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Trace mineral-vitamin¶	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated analysis:							
Digestible energy, Mcal/kg	3.45	3.45	3.46	3.45	3.46	3.44	3.44
CP, %§	13.2	15.0	16.7	15.0	16.7	15.0	16.7
Lysine, %	0.60	0.73	0.85	0.60	0.60	0.73	0.85
Chemical analysis, %:							
CP§	14.3	15.8	16.6	15.6	16.1	16.5	16.0
Lysine	0.68	0.78	0.90	0.73	0.69	0.76	0.89
Threonine	0.61	0.72	0.80	0.66	0.62	0.68	0.62
Histidine	0.38	0.45	0.54	0.40	0.42	0.43	0.37
Isoleucine	0.56	0.67	0.74	0.65	0.59	0.69	0.53
Valine	0.74	0.84	0.92	0.83	0.76	0.78	0.69

* **SBM** = soybean meal; **Iso-N** = iso-nitrogenous to the SBM diets; **Iso-Lys** = iso-lysinic to the SBM diets; **Med** = medium; **CP** = crude protein; all diets contained 0.70% Ca and 0.60% P.

Contained 99% crude fat (Fat Pak®100, Milk Specialties Co., Dundee, IL).

¶ Premix provided the following per kilogram of diet: Mg, 269 mg; Zn, 80 mg; Fe, 80 mg; Mn, 40 mg; Cu, 10 mg; I, 1 mg; Co, 0.4 mg; Se, 0.3 mg; vitamin A, 5,500 IU; vitamin D_3, 1,760 IU; vitamin E, 16.5 IU; menadione dimethylpyrimidinol bisulfite, 2.2 mg; riboflavin, 4.4 mg; d-pantothenic acid, 17.6 mg; niacin, 35.2 mg; vitamin B_{12}, 27.5 μg; choline, 95 mg.

§ Assumed the CP equivalent value of 281% for urea; diets were not analyzed for nonprotein nitrogen.

Slaughter Procedures. Pigs were slaughtered at the university's meat laboratory using conventional procedures. Carcass traits were assessed, and the weight of internal organs was determined as described previously by Chiba (8). The rate of lean accretion and proportion of carcass lean were estimated using equations reported by the NPPC (9).

Statistical Procedures. Data were analyzed as a generalized randomized block design (10) using the GLM procedure of SAS (11). Sex was used as a blocking criterion. The initial and final weights were included in the model as covariates for the growth data, whereas the final weight was used as a covariate for carcass and organ data. The treatment effects were evaluated using orthogonal contrasts: 1) Low vs other diets, 2) Med vs High diets, 3) SBM vs urea diets (average of Med and High), 4) Iso-N vs Iso-Lys diets (average of Med and High), 5) SBM vs urea diets (difference between Med and High), and 6) Iso-N vs Iso-Lys diets (difference between Med and High).

RESULTS

The results of amino acid analysis indicated that lysine contents of all diets were greater than intended values (Table 1). The reason for those differences is not apparent. The lysine contents of the two Iso-Lys diets were, however, similar to the Med and High SBM diets. Although a definite assessment can not be made because diets were not analyzed for nonprotein N, analyzed CP contents of the two Iso-N diets were relatively similar to the Med and High SBM diets.

There was no clear effect of dietary treatments on feed intake, but it ranged from 3.25 to 3.68 kg/day among pigs fed various diets (Table 2). Pigs fed the Low SBM diet tended to grow faster ($P = 0.09$) than those fed the Med and High diets (1.09 vs 1.02 kg/day). The level (Med vs High) and source of lysine and(or) N [SBM vs urea and(or) amino acids] or amino acid supplementation of urea diets (Iso-N vs Iso-Lys) had no effect on weight gain. Feed intake was numerically lower in pigs fed the Med Iso-Lys diet (3.25 kg/day) than those fed other urea diets, which resulted in a trend ($P = 0.10$) for pigs fed the Iso-Lys diets to utilize feed more efficiently for weight gain than for those fed the Iso-N diets.

There were no differences in the ultrasound BF at the beginning of the experiment (overall average, 15.8 $\pm$ 1.7 mm), indicating that the initial body composition was similar for all pigs. Pigs fed the Low diet had higher average carcass BF (36.4 vs 32.1 mm; $P < 0.05$), and tended to have higher 10th rib BF (33.1 vs 28.9 mm; $P = 0.10$) and smaller LMA (30.9 vs 33.9 cm^2; $P = 0.11$) than those fed other diets containing medium and high levels of lysine and(or) N. These differences were reflected in the carcass specific gravity (1.041 vs 1.046; $P < 0.05$) and proportion of carcass lean (44.7 vs 47.6%; $P = 0.08$). As in weight gain, the level and source of lysine and(or) N or amino acid supplementation had no effect on carcass traits. There was no clear effect of dietary treatments on the rate of lean accretion.

The weight of liver was higher ($P < 0.01$) in pigs fed the Med and High SBM diets than those fed the Med and High urea diets. Pigs fed the High diets had heavier ($P < 0.05$) kidneys than those fed the Med diets. The weight of kidneys increased as lysine and N levels increased from medium to high in pigs fed the SBM diets, but the difference between the Med and High diets was similar for those fed the Iso-N or Iso-Lys diets (SBM vs urea diets, $P = 0.06$).

DISCUSSION

Finisher pigs tend to consume feed in excess of that needed to meet their energy requirement for maximum protein accretion, and excess energy intake can increase the body fat content (12). As the dietary N content increases, a greater proportion of total energy is provided by amino acids rather than nonprotein energy sources. This lowers metabolizable energy content of the diet, and it has been suggested that deaminated amino acids are not utilized efficiently by pigs (12,13,14). Furthermore, the possible increase in the energy expenditure because of increased mass of internal organs (5,8,15)

and(or) whole-body protein turnover (16) may further reduce the energy status of pigs fed high-N diets. All these factors may lead to a reduction of energy available for excess fat accretion. The leanness of pigs, therefore, can be improved by increasing the N component of the diet above the requirement, even though a reduction of weight gain may be an inevitable consequence (12), and the increase in urinary N excretion is a potential environmental concern (17).

Weight gain of pigs tended to decrease as dietary lysine and(or) N increased from low to medium or high. On the other hand, pigs fed the Low diet had higher carcass BF and lower carcass specific gravity, and tended to have lower proportion of carcass lean than those fed the Med and High diets, indicating that a higher weight gain was achieved by the increased rate of fat accretion. There was no difference in weight gain among pigs fed three series of the Med and High diets regardless of the source of lysine and(or) N or amino acid supplementation of urea diets. Similarly, there was no effect of increasing dietary lysine and(or) N levels from medium to high on carcass BF. Although pigs fed the High diets seemed to have heavier metabolically active organs than those fed the Med diets as indicated by the kidney data, this increase was apparently caused primarily by changes observed in pigs fed the SBM diets. There was, therefore, no clear indication that feeding high levels of dietary lysine and(or) N induced metabolic and(or) physiological alterations, which can lead to a diminution of energy status of pigs. These results were not anticipated based on previous findings (4) and a fundamental assumption made for this research. As would be expected, neither carcass specific gravity nor proportion of carcass lean was affected by the increase in dietary lysine and(or) N levels from medium to high.

It is possible that the CP content of four urea diets (13.2% without urea) was inadequate to sustain an appropriate rate of protein synthesis in pigs because urea, unlike intact proteins, does not contribute carbon skeletons necessary for the synthesis of amino acids. Increasing dietary N by simply incorporating urea, therefore, may not have elicited appreciable metabolic and(or) physiological alterations that can lead to an increase in energy expenditures. It has been demonstrated that the rate of whole-body protein turnover, which has a high energy expenditure (18), in pigs can be increased by feeding diets high in the N content (16). This contention is, however, not applicable to response patterns observed in pigs fed the SBM diets. Therefore, there was no plausible explanation for the lack of response to the high levels of dietary lysine and(or) N in the carcass quality.

Providing dietary protein or amino acids above the requirement can increase the feed cost. To improve the carcass quality, however, providing adequate amounts of extra protein might be more important than the quality of protein sources as pointed out by Griffiths et al. (3). Assuming the adequacy of dietary supply of intact indispensable amino acids for protein synthesis, this implies that extra N may have additional role(s). It has been reported that body fat content of poultry can be reduced by excess dietary isoleucine or lysine (19) or glycine (20,21), and Cabel et al. (21) noted that certain amino acids may be involved in regulating lipogenesis.

The contention of Griffiths et al. (3) also implies that extra dietary N can be provided by inexpensive N supplements. Simple forms of nonprotein N (**NPN**) such as urea are considerably cheaper than intact protein sources (22). It has been demonstrated that pigs are capable of absorbing amino acids synthesized from ^{15}N-urea by intestinal bacteria (23), and can incorporate those amino acids into tissue proteins (24), indicating that they have the ability to utilize NPN. However, it is generally assumed that the amount of NPN utilized by pigs would be too small to elicit substantial beneficial effects on the performance because of their anatomical and metabolic limitations (25,26). The results of practical feeding experiments seem to support this general statement (e.g., 27,28).

Although, as mentioned before, there was no improvement in the carcass quality as dietary lysine and(or) N levels increased from medium to high, pigs fed the Med or High diets had lower

carcass BF and higher carcass specific gravity, and tended to have larger LMA and higher proportion of carcass lean than those fed the Low diet. Simply adding urea to increase dietary N (Iso-N) was equally effective as the SBM diets or amino acid supplementation of urea diets (Iso-Lys) in improving the carcass quality of finisher pigs. This finding was rather surprising because lysine, which was presumably the first limiting dietary amino acid in this research, and other indispensable amino acid contents of the two Iso-N diets were essentially the same as those of the Low SBM diet. It is well known that lysine and threonine do not participate in reversible transaminations (22). Therefore, NPN cannot make any contribution in meeting their requirements, and adequate amounts of those amino acids must be provided as such in the diet. Nevertheless, the overall utilization of diets was improved by the inclusion of urea, which agrees with a suggestion made earlier (25).

TABLE 2
Effects of Dietary Treatments on Growth Performance, Carcass Traits and Lean, and Organ Weight of Finisher Pigs*

				Urea diets				
	SBM diets			Iso-N		Iso-Lys		
Item#¶	Low	Med	High	Med	High	Med	High	CV, %
Growth Performance:								
Feed intake, kg/day	3.62	3.61	3.48	3.68	3.56	3.25	3.48	13.6
Weight gain, kg/day[a]	1.09	1.03	1.05	1.01	1.01	1.06	0.97	7.6
Gain:feed[b]	0.30	0.30	0.30	0.28	0.29	0.33	0.29	14.4
Carcass traits:								
Average BF, mm[c]	36.4	30.7	32.9	33.5	30.7	32.8	31.7	11.4
Tenth rib BF, mm[d]	33.1	28.0	27.1	30.7	29.2	29.0	29.4	18.4
LMA, cm^2	30.9	34.6	34.2	33.5	33.1	34.7	33.2	12.0
Specific gravity[e]	1.041	1.045	1.047	1.044	1.045	1.047	1.049	0.5
Estimated lean (containing 5% fat):								
Accretion, kg/day	0.28	0.30	0.31	0.28	0.28	0.30	0.28	21.8
Proportion, %[c]	44.7	48.4	48.4	46.6	47.1	47.7	47.1	7.3
Organ weight, kg:								
Liver[f]	1.51	1.61	1.67	1.51	1.51	1.45	1.52	8.8
Kidneys[g]	0.31	0.29	0.34	0.30	0.31	0.30	0.31	9.3

* **SBM** = soybean meal; **Iso-N** = iso-nitrogenous to the SBM diets; **Iso-Lys** = iso-lysinic to the SBM diets; **Med** = medium; **BF** = backfat thickness; **LMA** = longissimus muscle area.

Least squares means were based on six individually fed pigs per diet; both the initial (54.2 ± 5.5 kg) and final (103.2 ± 4.5 kg) weights were included in the model as covariates for growth performance, whereas the final weight was used as a covariate for the carcass and organ data.

¶ *P*-values: [a]Low vs other diets, $P = 0.09$; [b]Iso-N vs Iso-Lys diets (average of Med and High), $P = 0.10$; [c]Low vs other diets, $P < 0.05$; [d]Low vs other diets, $P = 0.10$; [e]Low vs others, $P = 0.08$; [f]SBM vs urea diets (average of Med and High), $P < 0.01$; [g]Med vs High diets, $P < 0.05$ and SBM vs urea diets (difference between Med and High), $P = 0.06$.

In summary, the results indicated that the carcass quality of finisher pigs was improved by increasing dietary lysine and(or) N levels from low to medium regardless of the source [SBM or urea and(or) amino acids]. Furthermore, simply incorporating urea to increase dietary N from low to medium and amino acid supplementation of urea diets were equally effective in enhancing the carcass quality of pigs, indicating that overall utilization of diets was improved by the inclusion of urea. There was, however, no improvement in the carcass quality of finisher pigs with further increases in dietary lysine and(or) N levels from medium to high.

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REFERENCES

1. Asche GA, Lewis AJ, Peo ER, Jr., Crenshaw JD. The nutritional value of normal and high lysine corn for weanling and growing-finishing swine when fed at four lysine levels. J Anim Sci 1985; 60:1412-28.

2. Chiba LI, Lewis AJ, Peo ER, Jr. Amino acid and energy interrelationships in pigs weighing 20 to 50 kilograms. II. Rate and efficiency of protein and fat deposition. J Anim Sci 1991; 69:708-18.

3. Griffiths L, Leeson S, Summers JD. Fat deposition in broilers: effects of dietary energy to protein balance, and early life caloric restriction on productive performance and abdominal fat pad size. Poult Sci 1977; 56:638-46.

4. Chiba LI, Ivey HW, Cummins KA, Gamble BE. Effects of hydrolyzed feather meal as a source of extra nitrogen on growth performance and carcass traits of finisher pigs. Anim Feed Sci Technol 1995; (In press).

5. Chiba LI. Effects of dietary lysine levels on the performance, carcass characteristics and organ weights of finishing pigs. J Anim Sci 1992; 70(Suppl 1):15 (Abstr).

6. NRC. Nutrient Requirements of Swine (9th ed). Washington, DC: National Academy Press, 1988.

7. AOAC. Official Methods of Analysis (14th ed). Washington, DC: Association of Official Analytical Chemists, 1984.

8. Chiba LI. Effect of dietary amino acid content between 20 and 50 kg and 50 and 100 kg live weight on the subsequent and overall performance of pigs. Livest Prod Sci 1994; 39:213-21.

9. NPPC. Procedures to Evaluate Market Hogs (3rd ed). Des Moines, IA: National Pork Producers Council, 1991.

10. Addelman S. The generalized randomized block design. Am Statist 1969; 23:35-36.

11. SAS. SAS/STAT® User's Guide (Release 6.03 Edition). Cary, NC: SAS Inst Inc, 1985.

12. Whittemore CT. Nutritional manipulation of carcass quality in pigs. In: Haresign W, Cole DJA, ed. Recent Advances in Nutrition. London: Butterworths, 1985: 149-56.

13. Schultz AR. Computer-based methods for calculating the available energy of proteins. J Nutr 1975; 105:200-7.

14. Just A. The net energy value of crude (catabolized) protein for growing pigs. Livest Prod Sci 1982; 9:349-60.

15. Chiba LI. Effects of nutritional history on the subsequent and overall performance and carcass traits of pigs. Livest Prod Sci 1995; (In press).

16. Reeds PJ, Fuller MF, Cadenhead A, Lobley GE, McDonald JD. Effects of changes in the intakes of protein and non-protein energy on whole-body protein turnover in growing pigs. Br J Nutr 1981; 45:539-46.

17. Lenis NP. Lower nitrogen excretion in pig husbandry by feeding: Current and future possibilities. Neth J Agric Sci 1989; 37:61-70.

18. Reeds PJ, Wahle KW, Haggarty. Energy cost of protein and fatty acid synthesis. Proc Nutr Soc 1982; 41:155-59.

19. Velu JG, Scott HM, Baker DH. Body composition and nutrient utilization of chicks fed amino acid diets containing graded amounts of either isoleucine or lysine. J Nutr 1972; 102:741-47.

20. Summers JD, Leeson S. Broiler carcass composition as affected by amino acid supplementation. Can J Anim Sci 1985; 65:717-23.

21. Cabel MC, Goodwin TL, Waldroup PW. Feather meal as a nonspecific nitrogen source for abdominal fat reduction in broilers during the finishing period. Poult Sci 1988; 67:300-6.

22. Lewis AJ. Amino acid in swine nutrition. In: Miller ER, Ullrey DE, Lewis AJ, ed. Swine Nutrition. Boston, MA: Butterworth-Heinemann, 1991: 147-64.

23. Niiyama M, Deguchi E, Kagota K, Namioka S. Appearance of ^{15}N-labeled intestinal microbial amino acids in the venous blood of the pig colon. Am J Vet Res 1979; 40:716-8.

24. Grimson RE, Bowland JP, Milligan LP. Use of nitrogen-15 labelled urea to study urea utilization by pigs. Can J Anim Sci 1971; 51:103-10.

25. Hoefer JA. The effect of dietary urea on the pig. In: Briggs MH, ed. Urea as a Protein Supplement. London: Pergamon Press, 1967: 429-53.

26. NRC. Urea and Other Nonprotein Nitrogen Compounds in Animal Nutrition. Washington DC: National Academy of Sciences, 1976: 88-94.

27. Wehrbein GF, Vipperman PE, Peo ER, Jr, Cunningham PJ. Diammonium citrate and diammonium phosphate as sources of dietary nitrogen for growing-finishing swine. J Anim Sci 1970; 31:327-32.

28. Kornegay ET. Supplementation of lysine, ammonium polyphosphate and urea in diets for growing-finishing pigs. J Anim Sci 1972; 34:55-63.

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