

Porcine Somatotropin Improves the Efficiency of Digestible Protein Use for Protein Deposition by Growing Pigs*

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ABSTRACT : A study was conducted to clarify the impact of recombinant porcine somatotropin (pST) on the efficiency of absorbed nitrogen use for protein deposition in growing pigs. Three levels of dietary crude protein (9.0, 11.5, 14.0% CP) were used. Each had either a sub-optimum or near optimum lysine:CP concentration (Low-lysine, 3.8 g/100 g CP and High-lysine, 5.5 g/100 g CP) in order to achieve different metabolic efficiencies for nitrogen deposition (ca. 45 vs. 60%). Twelve crossbred female pigs (59±4 kg BW) were placed in metabolism cages and fitted with bladder catheters. Each pig received an excipient injection daily for the first 10-d, a pST (5 mg/d) injection for the second 10-d, and then excipient for the last 10-d. Pigs were randomly assigned to one of six dietary treatments (2 pigs/diet) and fed 4 times per d at 92 g/kg BW^{0.75} (3× maintenance). Means for the excipient period were compared to means for the pST period. Urinary nitrogen (N) output declined in pST-treated pigs (p<0.01) irrespective of dietary protein content or lysine level. Nitrogen retention increased by an average of 11% (p<0.01) with pST treatment (726 vs. 803 mg N/kg^{0.75} BW/d). Forty-eight percent of the absorbed N was retained with Low-lysine diets, but this increased to 53% with pST injection (+11%, p<0.01). Pigs fed High-lysine diets retained 62% of absorbed N which increased to 69% with pST (+11%, p<0.01). The addition of lysine improved N use by 27% (High vs. Low, p<0.01), but the effect of lysine and pST was additive (+40%). Therefore, pST improves N retention and the efficiency of apparently absorbed N use in growing pigs (>60 kg). It does so with diets having the potential for either low or high efficiencies of N use (48% and 62%). More work is needed to determine if the partial efficiency of N use improves in direct proportion to pST dose since the improvement in protein deposition is a function of pST dose. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 7 : 1096-1103*)

Key Words : Growing Pigs, Amino Acids, Somatotropin, Metabolic Efficiency

INTRODUCTION

Exogenous porcine somatotropin (pST) regulates nutrient metabolism so that a greater proportion of absorbed nutrients are partitioned toward protein deposition and away from lipid (Boyd and Bauman, 1989; Vernon, 1989; Etherton and Smith, 1991). The dietary protein requirement would increase in direct proportion to pST-induced protein gain unless the efficiency of dietary protein use is improved (Boyd et al., 1991; NRC, 1994). Despite a substantial increase in the rate of protein gain for pST-treated pigs from 20 to 60 kg, only a marginal increase in dietary protein was required because the metabolic efficiency of amino acid use was improved (Campbell et al., 1990; Krick et al., 1993).

There is controversy about the relative change in amino acid requirement for pST-treated pigs during the

60 to 100 kg growth phase. Krick (1993) reported that the efficiency of dietary protein use by pST-treated pigs was higher than for control pigs. A 9% increase in dietary protein supported a dramatic increase in protein accretion (from 140 g/d to 235 g/d) with a response optimum dose of pST (120 ug pST/kg/d). However, Campbell et al. (1991) concluded that the protein requirement would increase in direct proportion to the increase in protein deposition since the efficiency of protein use was not changed by pST administration in growing intact male pigs (60 to 90 kg BW).

A major difference between the two studies is that the efficiency of apparently digested protein used for protein deposition in control pigs was different (ca. 40% vs. 60%, respectively). Estimates for pST-treated pigs were similar for both studies (ca. 60%). The discrepancy in estimates for control pigs is probably due to the fact that different dietary lysine:protein (CP) ratio's were used. Diets of Campbell et al. (1991) had a constant ratio of 6.5 g lysine/100 g CP, whereas the diets of Krick (1993) varied from a low of 3.5 to a high of 6.9 g/100 CP with increasing lysine level. It seems unlikely that pST would affect the metabolic efficiency of amino acid use at two adjacent phases of growth. A difference in gender (castrate, female vs. intact), diet strategy or experimental error seem more likely. The impact of

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pST dose on the metabolic efficiency of lysine use is unclear, but both groups used optimum or near optimum doses and injected daily. Protein deposition response is directly related to pST dose (Krick et al., 1992).

The present experiment was conducted to determine if recombinant pST can improve the efficiency of absorbed nitrogen use for nitrogen retention in pigs receiving 'low' (45%) and 'high' (60%) efficiency diets during the 60 to 85 kg growth phase of growth.

A more practical dose of pST was used to test this concept.

MATERIALS AND METHODS

Animals and treatments

Methods were approved by the Cornell University Animal Care and Use Committee. Twelve crossbred female pigs (Camborough 15 Sow × PIC 326 Sire; PIC USA, Franklin, KY) weighing 59 ± 4 kg were used in

Table 1. Composition of experimental diets

Item	CP (%)	Control diets			Lysine-supplemented diets		
		9.0	11.5	14.0	9.0	11.5	14.0
Ingredients, % as fed							
Corn ^a		50.50	64.43	78.40	50.50	64.43	78.40
Soybean meal (CP 48%) ^b		8.40	10.70	13.00	8.40	10.70	13.00
Starch		35.65	17.83	0	35.65	17.83	0
Corn oil		0	1.50	3.00	0	1.50	3.00
Dicalcium Phosphate		2.70	2.40	2.10	2.70	2.40	2.10
Limestone		0.70	0.85	1.00	0.70	0.85	1.00
Antibiotics ^c		0.50	0.50	0.50	0.50	0.50	0.50
Vitamin/trace mineral mix ^d		0.25	0.25	0.25	0.25	0.25	0.25
Salt		0.45	0.43	0.40	0.45	0.43	0.40
L-Lysine · HCl		0	0	0	0.19	0.25	0.30
DL-Methionine		0.17	0.22	0.27	0.17	0.22	0.27
L-Threonine		0.08	0.11	0.13	0.08	0.11	0.13
L-Tryptophan		0.02	0.02	0.02	0.02	0.02	0.02
L-Glutamic acid+L-Glycine ^e		0.58	0.76	0.93	0.39	0.51	0.63
Nutrients, as fed							
DE (Mcal/kg diet) ^f		3.6	3.6	3.5	3.6	3.6	3.5
Crude protein (N × 6.25)		9.2	11.4	13.6	9.1	11.5	13.5
Calcium		0.89	0.89	0.89	0.89	0.89	0.89
Phosphorus		0.70	0.70	0.70	0.70	0.70	0.70
Amino acids ^g , as fed							
Lysine		0.35 (0.35)	0.44 (0.45)	0.54 (0.57)	0.49 (0.50)	0.63 (0.61)	0.77 (0.71)
Methionine+Cystine		0.30 (0.29)	0.39 (0.39)	0.47 (0.47)	0.30 (0.29)	0.39 (0.39)	0.47 (0.48)
Threonine		0.35 (0.34)	0.44 (0.44)	0.54 (0.55)	0.35 (0.37)	0.44 (0.44)	0.54 (0.50)
Tryptophan		0.10 (0.10)	0.13 (0.13)	0.15 (0.14)	0.10 (0.10)	0.13 (0.13)	0.15 (0.14)
Isoleucine		0.31	0.39	0.48	0.31	0.39	0.48
Leucine		0.73	0.93	1.13	0.73	0.93	1.13
Valine		0.38	0.19	0.59	0.38	0.49	0.59
Histidine		0.19	0.25	0.30	0.19	0.25	0.30
Phenylalanine+Tyrosine		0.58	0.74	0.90	0.58	0.74	0.90

^a Contained the following nutrients (g per kg) : crude protein 76, lysine 2.3, methionine+cystine 1.4, threonine 2.5, tryptophan 0.5, isoleucine 2.6, leucine 8.9, valine 3.6, phenylalanine+tyrosine 5.5, and histidine 2.0.

^b Contained the following nutrients (g per kg) : crude protein 480, lysine 27.1, methionine+cystine 7.6, threonine 16.8, tryptophan 7.2, isoleucine 20.9, leucine 33.3, valine 23.6, phenylalanine+tyrosine 36.3, and histidine 11.2.

^c Contained the following antibiotics per kg diet : Chlorotetracycline · HCl 110 mg, Sulfamethazine 110 mg, Penicillin 44 mg.

^d Contained the following nutrients per kg diet : vitamin A 5,510 IU, vitamin D 1,320 IU, vitamin E 20 IU, vitamin K 2.2 mg, pantothenic acid 17.6 mg, riboflavin 4.4 mg, niacin 35.2 mg, choline 95.6 mg, vitamin B₁₂ 25.5 μg, Mg 270 mg, Zn 80 mg, Mn 40 mg, Cu 10 mg, I 1 mg, Se 0.3 mg.

^e Mixture 50:50 of each.

^f Calculated with NRC (1988) values for DE.

^g Calculated from analytical values of corn and soybean meal. Values in parenthesis confirmed by chemical analysis of complete diets.

a nitrogen retention assay. Pigs were randomly assigned to one of six dietary treatments (2 pigs/treatment). Each pig received an excipient injection (bicarbonate buffer) for the first 10-d period (excipient 1), a recombinant pST dose (5 mg/d; American Cynamid Company, Princeton, NJ) for the second 10-d period, and then excipient again for last 10-d period (excipient 2). Excipient or pST was injected i.m. in the neck at 1700 h daily. Porcine somatotropin was dissolved in sterile bicarbonate buffer at pH 9.4 (5 mg/ml) and then stored at 4°C for up to 12 d. This dose was in the range of the anticipated commercial dosage (3 to 5 mg/d). Body weight was measured on d 5 and d 10 of each period. The average body weight in the middle of the collection period was 64 ± 4 kg for excipient 1 period, 73 ± 5 kg for the pST period and 80 ± 5 kg for excipient 2 period.

Diets

Dietary treatments consisted of 3 levels of protein (9.0, 11.5 and 14.0%) each having 2 lysine to crude protein ratios (3.8 g/100 g CP and 5.5 g/100 g CP). Protein sources in control diets (3.8 g/100 g CP) consisted of corn and soybean meal; no supplemental lysine was used (table 1). Lysine-supplemented diets (5.5 g/100 g CP) approximated the ideal protein amino acid pattern suggested by Wang and Fuller (1990) and Baker and Chung (1992). The composition of control and lysine-supplemented diets were identical except for lysine content. L-glutamic acid and L-glycine were used to make the diets iso-nitrogenous. The highest protein diet at each lysine level was diluted by corn starch to form the lower protein diets. Pigs were fed a total of 92 g per kg BW^{0.75} at four daily intervals (0800, 1230, 1700 and 2100 h) using semi-automated feeders. This corresponds to 3 times the maintenance energy requirement (NRC, 1988). Pigs were given free access to water.

Housing and sample collection

Pigs were moved into an environmentally controlled room ($20 \pm 1^\circ\text{C}$ and 16:8 h light:dark cycle) 10 d before the first treatment began. They were housed and fed individually in metabolic cages during the study period. Foley catheters (14 Fr., 15 cc; Rüsck Manufacturing, Germany) were introduced into urinary bladders 36 h before feces collection started for the first period (on d 4 of each period). At the end of each period, catheters were removed immediately after urine and feces collections were completed and re-introduced 36 h before the next collection. Catheter insertion into the bladder was completed within 2 minutes while pigs were eating diets (described by Fuller et al., 1979). Total feces and urine were collected for the last 5 d and 4 d, respectively, of

each 10-d period. Feces were collected every 2 h from 0700 to 2300 h and stored at -20°C until the completion of collection. At the end of each 10-d period, all feces were thawed and homogenized using a food mixer. Sub-samples were stored at -20°C for future analysis. Total urine was collected into 20 L plastic jugs containing 400 ml of 10% HCl (v/v) to prevent N loss and microbial growth ($\text{pH} < 3$). Aliquots of urine were taken from the daily collection (17:00 to 17:00) and stored at -20°C . Blood samples were obtained from the anterior vena cava at the end of each 10-d period. Orts were collected from each pig daily, dried, combined at the end of each period, and analyzed to adjust N intake. Nitrogen retention was measured as the difference between N ingested and the amount of N lost in urine and feces. Apparent biological value (ABV) of N was calculated as $(\text{N retained}/\text{N absorbed}) \times 100$. Overall efficiency of N retention (N Eff) was determined as $(\text{N retained}/\text{N ingested}) \times 100$.

Chemical analysis

Ground corn and soybean meal were analyzed by proximate analysis (AOAC, 1980) and for amino acid composition (Krick et al., 1993) prior to diet formulation. Nitrogen, moisture and amino acid content of experiment diets were confirmed by analysis after diets were mixed. To prevent N loss during the drying process, 4 to 5 g of wet feces were used for N analysis (Van Soest and Robertson, 1985) and 5 ml of urine was used for N analysis. Feed, feces and urine were assayed in quadruplicate by the Kjeldahl method (AOAC, 1980). Tryptophan N was used as a reference to confirm N recovery during the Kjeldahl assay since N in this molecule is difficult to digest. Plasma urea N was determined by colorimetric assay (Sigma, 1985).

Statistical analysis

The experimental design involved two main effects (diet and pST) with pigs nested within diet and repeated measures on pST injection (Neter et al., 1990). Components of the analyses of variance are diet (df. 5), pigs (diet), pST injection (df. 2), diet \times injection and the error term (df. 12). Single-degree of freedom contrasts were made for the main effects; diet (protein, lysine, protein \times lysine), pST (excipient 1 vs. excipient 2; pST vs. excipient). The diet \times pST interaction was statistically significant for only the N digestibility comparison ($p < 0.05$). Analyses were performed using Minitab (1991).

RESULTS

Somatotropin injection did not affect N digestibility (table 2). This is consistent with previous results

Table 2. Effect of pST injection on nitrogen balance in growing pigs fed diets containing different levels of protein and lysine^a

Criterion	CP (%)	Control diets ^b			Lysine-supplemented diets ^b			SEM ^c (n=2)
		9.0	11.5	14.0	9.0	11.5	14.0	
Nitrogen intake (mg/kg BW ^{0.75} per d)	Excipient 1	1,276	1,581	1,891	1,262	1,583	1,869	14 ^d
	Excipient 2	1,240	1,584	1,870	1,262	1,553	1,849	
	pST	1,273	1,572	1,902	1,251	1,579	1,849	
Fecal nitrogen (mg/kg BW ^{0.75} per d)	Excipient 1	237	241	353	238	265	307	15 ^{d,e,f}
	Excipient 2	209	220	278	179	289	263	
	pST	184	212	316	185	295	287	
Urinary nitrogen (mg/kg BW ^{0.75} per d)	Excipient 1	545	672	775	392	493	561	25 ^{d,g,h}
	Excipient 2	544	686	840	402	466	655	
	pST	513	647	737	308	399	528	
Nitrogen retained (mg/kg BW ^{0.75} per d)	Excipient 1	495	669	764	633	825	1,001	19 ^{d,g,h}
	Excipient 2	487	679	752	682	798	935	
	pST	576	714	850	759	885	1,035	
Apparent nitrogen digestibility (%)	Excipient 1	81.5	84.8	81.3	81.2	83.3	83.5	0.9 ^{e,i}
	Excipient 2	83.2	86.1	85.1	85.8	81.4	85.8	
	pST	85.5	86.5	83.4	85.2	81.3	84.5	
Apparent biological value (%)	Excipient 1	47.6	49.9	49.6	61.8	62.6	64.1	1.4 ^{g,h}
	Excipient 2	47.3	49.7	47.3	62.9	63.1	58.7	
	pST	52.9	52.5	53.5	71.2	69.0	66.3	
Overall efficiency of nitrogen use (%)	Excipient 1	38.7	42.3	40.4	50.1	52.1	53.6	1.2 ^{g,h,j}
	Excipient 2	39.3	42.8	40.3	54.0	51.4	50.4	
	pST	45.3	45.4	44.7	60.7	56.1	56.0	

^a Data presented as treatment means.^b Lysine concentration per 100 g CP was 3.8 g for control diets and 5.5 g for lysine-supplemented diets.^c Standard error of mean.^e Excipient 1 vs. Excipient 2 (p<0.01).^g Lysine concentration (p<0.01).ⁱ Hormone injection × protein level (p<0.05).^d Protein level (p<0.01).^f Protein level × lysine concentration (p<0.01).^h pST vs. Excipient (p<0.01).^j Protein level × lysine concentration (p<0.05).**Table 3.** Effect of pST injection and lysine supplementation on nitrogen metabolism^a

CP (%)	Treatment	NR (mg) ^{b,c}	Change (%) ^d	ABV (%) ^e	Change (%) ^d	N Eff (%) ^f	Change (%) ^d	Lys Eff (%) ^g	Change (%) ^d
9.0	Control	490	-	47.3	-	39.0	-	10.2	-
	+pST	576	+17.6	52.9	+11.8	45.2	+15.9	11.9	+16.0
	+Lys	656	+33.9	62.3	+31.7	52.0	+33.3	9.5	- 7.5
	+pST+Lys	758	+54.7	71.1	+50.3	60.6	+55.4	11.0	+ 7.6
11.5	Control	673	-	49.8	-	42.5	-	10.8	-
	+pST	713	+ 5.9	52.4	+ 5.2	45.4	+ 6.8	11.5	+ 6.8
	+Lys	810	+20.4	62.8	+26.1	51.7	+21.6	9.7	-10.0
	+pST+Lys	885	+31.5	68.9	+38.4	56.0	+31.8	10.6	- 1.9
14.0	Control	757	-	48.4	-	40.2	-	9.6	-
	+pST	849	+12.2	53.5	+10.5	44.6	+10.9	10.7	+11.0
	+Lys	966	+27.6	61.4	+26.9	52.0	+29.4	9.9	+ 3.4
	+pST+Lys	1,034	+36.6	66.2	+36.8	55.9	+39.1	10.6	+10.7
Mean	Control	640	-	48.5	-	40.6	-	10.2	-
	+pST	713	+11.4	52.9	+ 9.1	45.1	+11.1	11.3	+10.8
	+Lys	811	+26.7	62.2	+28.2	51.9	+27.8	9.7	- 4.1
	+pST+Lys	892	+39.4	68.7	+41.6	57.5	+41.6	10.7	+ 5.4

^a Data presented as means.^b Nitrogen retention (mg/kg^{0.75} BW per d).^c No difference in N intake within the same protein level (p>0.10).^d Improvement over control within the same protein level.^e Apparent biological value : calculated as (N retention/N absorbed) × 100.^f Overall efficiency of N retention : calculated as (N retention/N intake) × 100.^g Lysine efficiency for estimated protein gain : calculated as (6.25 × N retention/lysine intake) × 100.

(Verstegen et al., 1990; Wray-Cahen et al., 1991; Noblet et al., 1992 and 1993). However, pigs receiving the excipient during the last 10-d period showed a small improvement (ca. 2%) when compared to pigs receiving the excipient during the first 10-d ($p < 0.01$, table 2). To minimize the period effect in pigs receiving the excipient, the average apparent biological value (ABV) was calculated using means of N digestibility for periods 1 and 3 (table 3).

Nitrogen intake and output (in urine and feces) increased as dietary protein level increased (table 2, $p < 0.01$). Urine N loss decreased with pST injection and lysine supplementation ($p < 0.01$). The amount of N retained during excipient 1 and excipient 2 was similar ($p > 0.10$), but increased with protein level and pST treatment ($p < 0.01$). The efficiency with which total N intake was used for N retention was improved with pST and lysine addition ($p < 0.01$), but not by protein level. The apparent biological value (ABV; $[\text{retained N}/\text{absorbed N}] \times 100$) for dietary N improved with lysine addition and pST injection ($p < 0.01$) at all protein levels (figure 1). Apparent biological value was similar for excipient 1 and 2 ($p > 0.10$). Plasma urea nitrogen (PUN) was lower for pST treated pigs, lysine addition and protein level (figure 2; $p < 0.01$).

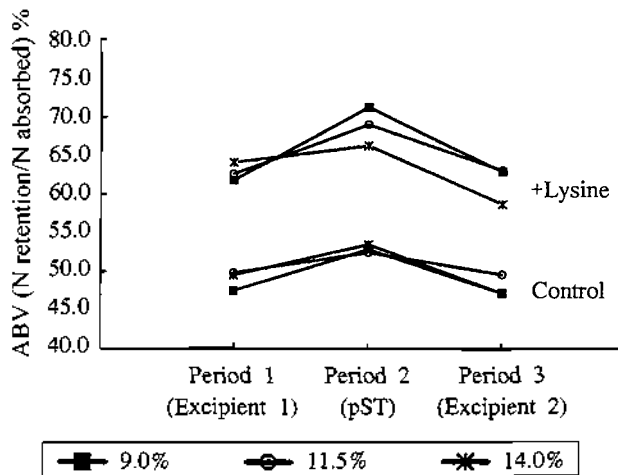


Figure 1. Change in apparent biological values (ABV) before, during and after pST administration in growing pigs. Each pig received excipient for the first 10 d and then 5 mg of pST i.m. for the second 10 d. They received excipient again for 10-d after withdrawal of pST. Effects of pST and lysine treatments were significant ($p < 0.01$). No significant difference was observed between period 1 and 3 ($p > 0.10$). SEM=1.37 (n=2)

The effect of pST and lysine addition on the partition of N is summarized in table 3. Excipient treated pigs that were fed low lysine diets (3.8 g/100 g CP) retained approximately 48% of apparently

absorbed N while those fed high lysine diets (5.5 g/100 g CP) retained 62% of the absorbed N. These are remarkably close to the efficiencies that were targeted (45% and 65% respectively). When pigs received the low lysine diets and pST, they retained 53% (vs. 48%) of absorbed N. Porcine somatotropin injection also improved retained N to 69% (vs. 62%) for pigs fed the near optimum high lysine diets. The extent to which N use was improved by pST injection compared to lysine addition is presented in figure 3. On average pST improved the efficiency of absorbed N by 11% ($p < 0.01$) and lysine improved N utilization by 27% ($p < 0.01$). The effects of pST and lysine were additive so that their combined effect was similar to the sum of their individual effects (ca. 40%).

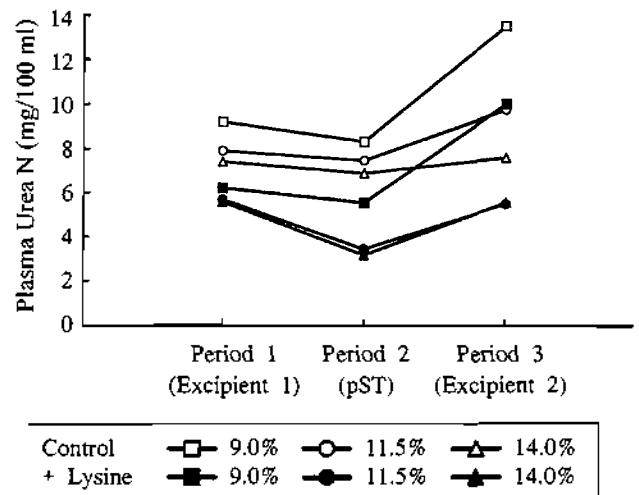


Figure 2. Plasma urea-N concentration (mg/100 ml) before, during and after pST administration in growing pigs. Each pig received excipient, pST (5 mg/d) and excipient again for the first, second, and last 10 days respectively. Blood was collected from the anterior vena cava at the end of each 10-d period. There were significant effects of protein level ($p < 0.01$), lysine supplementation ($p < 0.01$), and pST injection ($p < 0.01$). SEM=1.23 (n=2)

The efficiency of lysine use for protein gain (Lys Eff) was approximated by $N \text{ retention} \times 6.25$ divided by lysine intake (table 3 and figure 4). This procedure is appropriate for relative comparison only since $N \text{ retention} \times 6.25$ overestimates actual protein deposition in pigs by 8-12% (Lee, 1995). The efficiency of lysine use improved when pigs received the pST injection ($p < 0.01$), but this was greater for pigs fed the low lysine diets as compared to high lysine diets ($p < 0.01$). The effect of pST injection and lysine addition on the partition of ingested N is summarized in figure 5. Porcine ST did not change the amount of N in feces, but reduced urinary N excretion. It

resulted in increased N retention and efficiency of N utilization. The combination of pST and proper lysine proportion decreased urine N output by 40%.

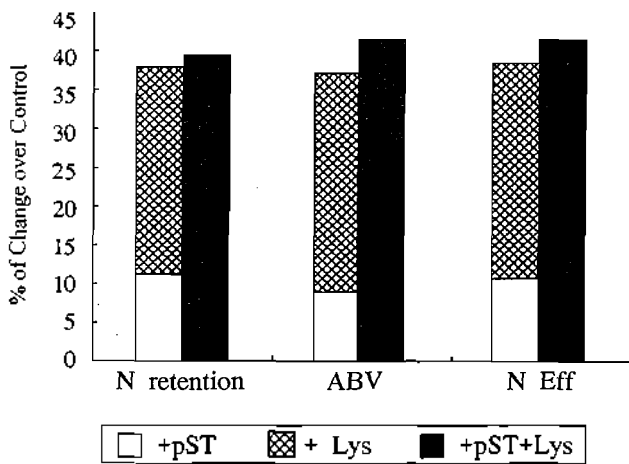


Figure 3. Effect of pST injection and lysine supplementation on N retention, apparent biological value (ABV) and overall efficiency of N use for N retention (N Eff) in growing pigs. Values for change (%) represent the improvement compared to controls. Summation of the responses to pST injection alone and lysine supplement alone was similar to the response to pST plus lysine. This indicates that the effects of pST and lysine on N metabolism are additive. Each value is the mean from pigs fed the diets containing 3 different levels of protein.

DISCUSSION

Our objective was to determine if elevated ST levels improve the efficiency with which absorbed N is used for protein deposition. We conducted a rigorous test involving 3 levels of dietary protein (deficient and near adequate) with each having sub-optimum or near optimum lysine:CP concentrations. Diets with low-lysine levels (3.8 to 4.0% of CP) were regarded as low efficiency diets and lysine-supplemented diets (5.5% of CP) regarded as high efficiency. The ABV for control pigs fed low-lysine diets averaged 48% (mean for three protein levels) but increased to 62% with lysine supplementation. Lysine addition improved the efficiency of absorbed N use (+27%) at all protein levels for both control and ST groups (table 3 and figure 3). The ABV of dietary N was improved by an average of 11% with ST and was additive with the improved lysine:protein ratio. The ability of ST to improve absorbed N efficiency is consistent with the earlier reports with smaller pigs (20 to 60 kg BW; Campbell et al., 1990; Krick et al., 1993). It confirms work with pigs weighing more than 60 kg (Krick, 1993; Noblet et al., 1993) and disagrees with the report of Campbell et al. (1991).

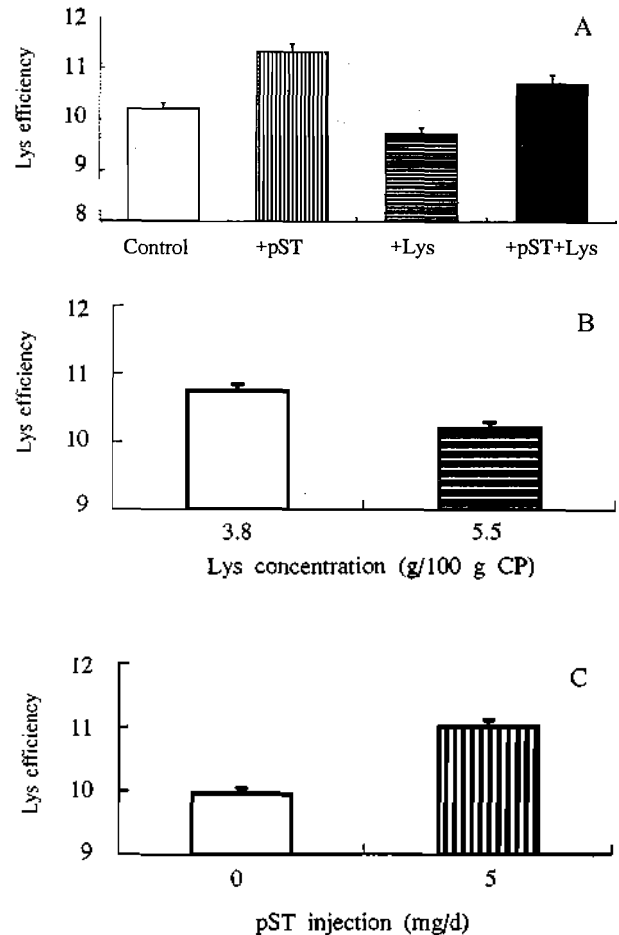


Figure 4. Effect of pST injection and lysine supplementation on the efficiency of lysine use (Lys Eff = $6.25 \times \text{N retention} / \text{lysine intake}$) in growing pigs. Panel 'A' shows the effect of pST and lysine treatment. Values represent means from three different levels of protein. Panel 'B' indicates that pigs fed control diets (3.8 g lysine/100 g CP) utilized lysine more efficiently than those fed a higher level of lysine ($p < 0.01$). Columns in panel 'B' present means of 18 observations. Panel 'C' illustrates that pST-treated pigs are superior to excipient-treated pigs in dietary lysine use for N retention ($p < 0.01$). Data in panel 'C' represent means of 24 observations for excipient-treated pigs and 12 values for pST-treated pigs. Bars represent means \pm SEM.

The apparent discrepancy between Campbell et al. (1991) and Krick (1993) in the ability of ST to improve the partial efficiency of lysine use by late growing pigs is not clear. It is possible that both experiments gave the correct result under the conditions imposed. The former involved intact males, which possess an endocrine advantage that leads to greater rates of protein deposition. The impact of being intact (vs. castrate) on the metabolic efficiency of N use has not been adequately tested. It is conceivable that ST could not increase the metabolic

efficiency further (0.62 for apparently absorbed protein), if the efficiency level was at a 'physiological' maximum for practical diets. The efficiency for lysine is expected to be greater than 0.62 since the dietary protein was not perfectly balanced for all amino acids. The study by Krick (1993) involved females and castrate males and involved a less than optimum lysine:protein balance which resulted in a lower metabolic efficiency of protein and lysine use. This might have afforded more of an opportunity for a ST-mediated response.

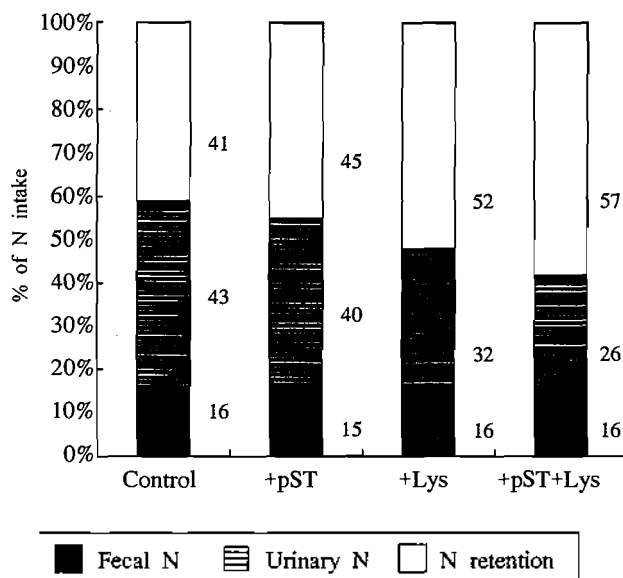


Figure 5. Effect of pST administration and lysine supplementation on partitioning of ingested nitrogen in growing pigs. Each value presents the mean from pigs fed the diets containing 3 different levels of protein. There were significant differences in urine N excretion ($p < 0.01$) and N retention ($p < 0.01$) between pigs receiving pST and excipient. The effects of lysine supplementation on urine N loss and N balance were also significant ($p < 0.01$). Columns indicate fecal N, urinary N and N retention as % of N intake.

The two main criticisms of the earlier work by the reports of Campbell and Krick was noted by Krick (1993) and the NRC (1994). Campbell et al. (1991) restricted energy intake so that only 119 g of whole-body protein deposition per d resulted for the control group. This allowed only two points to define the linear portion of the response curve and the range was relatively narrow. The sub-optimum lysine:protein balance used by Krick (1993) may have afforded a greater opportunity for response to pST improvement in the metabolic efficiency of lysine than appropriate. Noblet et al. (1993) conducted a more trustworthy study with approximately 60 kg pigs. ST injection

induced an average 11% improvement in the efficiency of N use over a range of N intakes, which is similar to the result of the present study. However, porcine ST injection improved the efficiency of N use at maximum N gain by 20% when compared to controls.

The evidence that exogenous pST improves the efficiency of absorbed amino acid use for protein accretion is now unequivocal. The other studies with pigs that are in agreement with this report cover a relatively wide range of growth (Campbell et al., 1990; Krick et al., 1993; Noblet et al., 1993). They are supported further by similar results with growing cattle (Houseknecht et al., 1992) and lambs (Beermann et al., 1990). Porcine somatotropin dose may affect the extent to which the absorbed N is used for N gain. Krick et al. (1992) determined that the optimum dose level of pST for maximum protein accretion was 150 μ g/kg bw per day but a similar study has not been conducted relative to changes in the efficiency of lysine use.

The mechanism by which pST improves the efficiency of protein deposition is not clear. Tomas et al. (1992) found that pST treatment increased both protein synthesis and breakdown in growing pigs. Since the increment of protein synthesis rate was greater than observed for breakdown, pST-treated pigs retained more N than did control pigs fed an equal amount of protein. This study also showed that urinary urea N excretion in the pST group was lower than for controls, simultaneous with a decrease in total urinary N excretion.

IMPLICATIONS

The present study confirms that pST improves the ability for protein deposition and the efficiency of absorbed protein use by growing pigs weighing more than 60 kg. The evidence that exogenous pST improves the efficiency with which absorbed amino acids are utilized for protein accretion in castrate and female pigs is unequivocal. We showed that the improvement is achievable when amino acid balance is inferior or optimized (e.g. basal N efficiency of 48% or 62%). We showed that pigs fed practical diets (properly balanced for amino acids) have a partial efficiency for absorbed protein of approximately 0.62. Absorbed lysine may be slightly higher but not more than 0.69, which agrees with our quantitative estimate (Lee, 1995 and Lee et al., 1998). The ability of pST to improve the partial efficiency in intact male pigs (> 60 kg BW) is unclear. More work is needed to (1) characterize the relationship of pST dose vs. lysine efficiency, and (2) to determine the lysine efficiency of lysine use among intact, castrate and female pigs.

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