GROWTH HORMONE, INSULIN AND GLUCOSE PLASMA PATTERNS IN GILTS SELECTED FOR RAPID VERSUS SLOW GROWTH RATE

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Story in Brief

Fifteen gilts from two lines of swine developed from within line matings of a composite of purebred Duroc, Landrace, Spot, Hampshire and Yorkshire breeds selected for rapid versus slow growth through five generations during the growing-finishing period were examined for differences in their twelve hour plasma profiles of growth hormone, insulin and glucose. Marked differences in the responses of plasma growth hormone, insulin and glucose profiles over time between growth lines were observed. Mean growth hormone concentrations were greater for slow growth line versus rapid growth line gilts. Differences in mean growth hormone concentration were paralleled by a greater plasma profile area for slow growth line than rapid growth line gilts. Mean maximum growth hormone concentration and mean peak amplitude also tended to be greater for slow growth line than rapid growth line gilts. Insulin concentrations were higher for rapid growth line as compared to slow growth line gilts. Plasma glucose levels were different between the two lines, with rapid growth line gilts exhibiting higher plasma glucose concentrations and greater plasma profile area than slow growth line gilts. These results indicate the suggested diabetogenic effect of growth hormone may be evident in rapidly growing pigs which differ in their secretory patterns of growth hormone but which exhibit lower overall mean growth hormone concentrations.

(Key Words: Growth hormone, Insulin, Glucose, Swine)

Introduction

For many years the focus of the livestock industry has been the optimization of genetic potential and environmental factors which impact production and ultimately affect the rate and composition of postweaning growth. Through improvements in herd health, reproduction, selection programs, nutrition and environmental physiology; considerable progress in production efficiency has been attained. Recent development of techniques with the potential of producing unlimited quantities of specific regulatory proteins has shifted emphasis toward the investigation of new methods to produce more rapid physiologically integrated improvements in growth and lean tissue feed conversion.

The endocrine system has been recognized as a key regulator of the growth process, and is therefore an important link between the genetic and ultimate phenotypic expression of economically important traits

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(Buhlinger et al., 1978; Chung et al., 1985). The manipulation of the endocrine system, therefore, may be a viable means whereby more rapid improvements in production efficiency can be achieved. Hence, a clear understanding of the impact of current production practices, such as selection for growth rate on the endocrine system is requisite to the application of this technology to the livestock industry.

This study was undertaken to examine how selection for increased growth rate is related to the level and pattern of two growth-related hormones and a metabolic nutrient. The plasma profiles of porcine growth hormone, porcine insulin and glucose in young gilts from two lines selected for rapid versus slow growth were assessed to more clearly define the influence of selection for growth on the endocrine system of the pig.

Materials and Methods

Two lines of pigs developed from within line matings of a composite of purebred Duroc, Landrace, Hampshire, Spot, and Yorkshire breeds were selected for five generations during the growing-finishing period for rapid versus slow growth. Litters were kept with their dams until weaning at 8 weeks of age and then grouped with genetic contemporaries to yield a density of 16 to 18 pigs per pen per genetic group. Creep rations were formulated to contain 18% crude protein. The growing-finishing rations which were fed beginning at 12 weeks of age was formulated to contain 16% and 14% crude protein, respectively.

Data obtained from previous generations of these lines include individual gain, pen feed efficiency as well as feed efficiency and gain of full versus limit fed (90%) pairs, and ultrasonic backfat measurements.

For this experiment, eight gilts from the rapid growth line with an average bodyweight of 116 lb. and average daily gain of 1.52 lb./day, and seven gilts from the slow growth line with an average bodyweight of 114 lb. and an average daily gain of 1.23 lb./day were utilized. A summary of growth and carcass characteristics of the 1985 October-September farrowing population of barrows and gilts from which pigs were selected for study is shown in table 1. Pigs from the rapid growth line grew 25% faster, had 6% greater backfat and produced carcasses that were 17% fatter compared to slow growth line pigs. Conversely, slow growth line barrows and gilts produced carcasses that were approximately 11% leaner compared to rapid growth line pigs. Pigs most closely performing at the average of each selected growth line were chosen for the experiment. Characteristics of the sample population are listed in table 2.

A tygon, microbore tubing catheter was placed intravenously in the proximity of the cranial vena cava of each animal. Ketamine-sulfate anesthesia, using the prescribed dosages for intramuscular use in 110 lb. swine was used in this procedure. Following catheterization, pigs were allowed to recover for 72 hours, to minimize effects of surgical stress on hormonal profiles. For the duration of an adaptation period and experiment, pigs were maintained in individual steel metabolism crates at an average ambient temperature of 77^{0} F. A 14 hour light:10 hour dark lighting cycle was imposed with an incandescent source to be consistent with the current photoperiod. A total of 4 lb./day of a corn-soybean diet formulated to contain .65% lysine was consumed daily

Table 1. Summary of selected growth and carcass characteristics of barrows and gilts from the October-September farrowing.

	GROWING PHASE				220 lb.		
		ADG			PROBE		
LINE	No.	(lb/day)	F/G[a]	FI[b]	BF(in)	%LEAN	%FAT
RGL	285	1.63	2.76	7.94	1.24	37.62	19.71
SGL	185	1.31	2.77	4.51	1.16	41.64	16.81

[a] Feed efficiency, lb. feed/lb. gain.

[b] Feed intake, lb. feed/day.

Table 2. Sample population characteristics.

LINE	No.	Weight (lb)	ADG (lb/day)	AGE (day)
RGL	8	115.7	1.52	114
SGL	7	113.7	1.23	130

(table 3). Meals were offered from 0600 to 0700 hours and again at 1700 to 1800 hours. Free access to water was provided.

The experiment was designed to examine plasma growth hormone, insulin and glucose plasma profiles, in eight rapid and seven slow growing gilts. At 0600 hour on the sampling day, 10 ml blood samples were obtained at 20-minutes intervals for a 12 hour period. Following centrifugation, plasma was harvested and frozen until laboratory analyses were performed.

Immunoreactive plasma insulin and porcine growth hormone were estimated by radioimmunoassay, while glucose concentrations were assayed colorimetrically.

Data were analyzed so that selection line differences in mean concentration and time profiles for insulin, growth hormone and glucose could be examined. The dynamics of the profiles for these characteristics were evaluated with a procedure that defines and calculates characteristics of secretory events.

Table 3. Composition of diet.

Item	%
Ingredient Composition[a]	
Corn, yellow	81.80
Soybean meal	15.65
Dicalcium phosphate	1.15
Calcium carbonate	.80
Salt	.35
Vitamin-trace mineral premix[b]	.25
Chemical Composition[a]	
Calcium	.62
Phosphorus	.54
Crude Protein	14.00
Lysine	.65

[a] As is basis.

[b] Supplied 4,000,000 IU vitamin A, 3,000,000 IU vitamin D, 4 g riboflavin, 20 g pantothenic acid, 30 g niacin, 800 g of choline chloride, 15 mg vitamin B_{12}, 10,000 IU vitamin E, 2 g menidione, 200 mg iodine, 90 g iron, 20 mg manganese, 10 g copper, 90 g zinc and 100 mg selenium per ton of feed.

Results and Discussion

A comparison of plasma profile area between slow growth line and rapid growth line gilts for growth hormone, insulin and glucose is presented in table 4. Glucose plasma profile area was greater for rapid growth line compared to slow growth line gilts ($P<.05$). Differences in insulin concentration tended to be higher for the rapid growth line, however, differences between selection lines were non-significant. Conversely, growth hormone plasma profile area was greater for the slow growth line ($P=.08$).

Comparisons of glucose plasma parameters are presented in table 5. Overall glucose concentrations, which are the arithmetic average of all temporal concentrations, were higher ($P<.05$) for rapid growth line than slow growth line gilts. Likewise, smoothed mean baseline concentrations, the mean of all temporal concentrations not contributing to pulse events, were higher ($P<.05$) for rapid growth line versus slow growth line gilts. Number of peaks over the 12 hour period were greater ($P<.10$) for rapid growth line compared to slow growth line gilts, 8.25 versus 6.50, respectively. There were no differences in maximum, minimum, average peak amplitude, peak duration or interpeak interval for

Table 4. Plasma profile areas for growth hormone, insulin and glucose in rapid and slow growth line gilts.

PLASMA PROFILE	SELECTION LINE	AREA[a]	SEM
Glucose	SGL	62139.8[b]	1053.7
	RGL	66062.8[c]	1178.1
Insulin	SGL	17829.2	526.9
	RGL	18333.2	471.3
Growth Hormone	SGL	2506.2[d]	104.6
	RGL	2219.7[e]	93.6

[a] Area = Total Area - Baseline Area.

[bc] Means are different (P<.05).

[de] Means are different (P=.08).

glucose between selection lines. Differences in the overall and smoothed mean concentrations of glucose were associated with higher (P< .0001) overall insulin concentrations in rapid growth line versus slow growth line gilts (table 6). However, smoothed baseline insulin concentrations were not significantly different between lines. Maximum insulin levels and mean peak amplitude both tended to be higher for the rapid growth line, but were not significantly different. Likewise, pulse duration and interpeak intervals both tended to be longer in rapid growth line gilts, however, no significant differences were observed.

Comparisons of growth hormone plasma profile parameters are presented in table 7. Overall mean growth hormone concentrations were higher for the slow growth line (P=.06) while smoothed mean growth hormone concentrations were not significantly different. The higher overall growth hormone levels were paralleled by higher mean peak amplitude and maximum concentrations (P< .10) for slow growth line compared to rapid growth line gilts.

In order to determine if time of day at which growth hormone, insulin and glucose plasma events occurred was different between selection lines, comparisons of the number of events of each parameter in the AM (0600 to 1200 hours), and PM (1220 to 1800 hours) were performed (table 8). The number of secretory events between selection lines were not different for growth hormone or insulin, however, rapid

Table 5. Glucose plasma profile parameters in rapid and slow growth line gilts.

	PLASMA GLUCOSE[a]			
	SGL		RGL	
Overall [Glucose] (mg/dl)	84.97	(1.42)[b]	90.50	(1.59)[c]
Smoothed [Glucose] (mg/dl)	80.41	(1.53)[b]	86.52	(1.70)[c]
Maximum [Glucose] (mg/dl)	110.40	(4.22)	100.20	(3.77)
Minimum [Glucose] (mg/dl)	72.12	(3.79)	67.82	(3.39)
Number of Peaks	6.50	(.67)[d]	8.25	(.50)[e]
Peak Amplitude (mg/dl)	14.90	(6.81)	19.45	(6.09)
Peak Duration (min)	68.66	(6.22)	64.12	(5.56)
Inter-Peak Interval (min)	170.69	(10.49)	151.04	(9.39)

[a] Values in parenthesis denote SEM.

[bc] Means differ ($P<.05$).

[de] Means differ ($P<.10$).

growth line gilts displayed a greater number of glucose pulses in the AM compared to slow growth line gilts ($P<.10$). For both selection groups the number of pulse events tended to be greater in the AM versus the PM.

The analysis of the pattern of growth hormone, glucose and insulin over the 12 hour period showed different ($P<.05$) plasma profiles between the two selection lines. The results of this experiment have demonstrated that selection for growth rate results in marked differences in the plasma profile characteristics of plasma growth hormone, insulin and glucose in young, growing swine.

At equal bodyweights, rapid growth line carcasses exhibited more backfat and greater lipid to lean ratio than the slow growth line. These carcass characteristics are consistent with reports of swine populations in which selection for growth rate was imposed (Buhlinger et al., 1978).

In this study overall plasma growth hormone concentrations were slightly lower in rapid growth line gilts which is consistent with observations from studies examining growth hormone levels in more extreme populations of lean and obese pigs, such as the Yorkshire versus the Ossabaw breed, respectively (Wangsness, et al., 1977). In these and other similar experiments conducted with rats (Martin and Gahagan, 1977), and humans (Copinschi et al., 1967), lower circulating growth

Table 6. Insulin plasma profile parameters in rapid and slow growth line gilts.

	PLASMA INSULIN[a]			
	SGL		RGL	
Overall [Insulin] (uU/ml)	22.27	(.72)[b]	25.76	(.64)[c]
Smoothed [Insulin] (uU/ml)	21.55	(.89)	21.51	(.79)
Maximum [Insulin] (uU/ml)	39.89	(2.44)	42.86	(2.19)
Minimum [Insulin] (uU/ml)	15.04	(.93)	15.18	(.83)
Number of Peaks	6.75	(.55)	6.62	(.49)
Peak Amplitude (uU/ml)	9.57	(1.22)	12.39	(1.09)
Peak Duration (min)	55.76	(7.64)	63.57	(6.83)
Inter-Peak Interval (min)	185.31	(25.40)	195.15	(22.72)

[a] Values in parenthesis denote SEM.

[bc] Means differ (P<.0001).

hormone concentrations have been noted in genetically obese individuals. Therefore, the slightly lower growth hormone levels of the rapid growth line in the present experiment may be partially explained by their relatively greater proportion of adipose to lean tissue. Furthermore, recognizing the possible lipolytic action of growth hormone in adipose tissue, both in vivo and in vitro, the relatively lower carcass lipid of the slow growth line versus the rapid growth line may be related to higher levels of circulating growth hormone in the slow growth line.

Given the stimulatory effect of growth hormone on growth rate, the significantly lower growth hormone concentrations of the rapid growth line conflicts with their more rapid growth pattern. These observations suggest the possibility that factors other than overall plasma concentrations of somatogenic hormones and nutrients may be biologically important in accurately relating plasma profile characteristics such as these with differential rates of growth. This possibility has been suggested based on similar findings by other groups (Klindt et al., 1986; Etherton and Kensinger, 1984).

Table 7. GH plasma profile parameters in rapid and slow growth line gilts.

	PLASMA GH[a]			
	SGL		RGL	
Overall[GH] (ng/ml)	4.06	(.14)[b]	3.17	(.13)[c]
Smoothed [GH] (ng/ml)	2.56	(.23)	2.32	(.20)
Maximum [GH] (ng/ml)	11.13	(.98)[d]	6.88	(.74)[e]
Minimum [GH] (ng/ml)	1.43	(.05)	1.37	(.04)
Number of Peaks	6.50	(.83)	6.88	(.74)
Peak Amplitude (ng/ml)	3.60	(.39)[d]	2.60	(.34)[e]
Peak Duration (min)	62.27	(6.71)	56.36	(6.00)
Inter-Peak Interval (min)	160.89	(20.56)	171.35	(18.34)

[a] Values in parenthesis denote SEM.

[bc] Means differ (P=.06).

[de] Means differ (P<.10).

Due to the lipogenic nature of insulin on adipose tissue, it was not surprising that rapid growth line gilts exhibited significantly higher circulating insulin concentrations given their greater percentage of backfat and carcass lipid. These observations are consistent with those of similar studies examining the role of insulin in growth and development. Hoffman et al. (1983) showed selection for backfat thickness in swine was accompanied by elevated fetal plasma insulin in the high backfat line. Conversely, Hetzer and Miller (1973) clearly demonstrated that selection against backfat in swine resulted in decreased adipose tissue lipogenic capacity. In addition, in studies also examining the relation to feed intake in hyperinsulinemic individuals, hyperphagia and excessive body weight gain have been observed. Consistent with these findings, the rapid growth line population from which gilts in this study were selected exhibited higher feed intake in relation to slow growth line pigs. Hence, differences in growth rate of the rapid growth line may be partially attributable not

only to greater levels of lipid accretion, but also higher levels of feed intake.

Results of previous studies have suggested an exogenous growth hormone-mediated antagonism of insulin action (Chung et al., 1985). There has been much controversy as to whether these diabetogenic, as well as lipolytic actions of growth hormone are mediated by a non-growth hormone contaminant of the hormone preparations (Goodman and Gritching, 1985). In this study, although plasma insulin levels were slightly higher in rapid growth line gilts, glucose concentrations were also significantly higher, possibly suggesting a mild tissue insensitivity to insulin in this line. This effect, however, was apparent with lower overall plasma growth hormone concentrations in the rapid growth line. This apparent inconsistency with previous reports of the suggested diabetogenic effect of growth hormone may indicate that insulin antagonistic effects are displayed only by endogenous growth hormone. In addition, lower levels of growth hormone in the rapid growth line may indicate a greater tissue sensitivity to growth hormone, requiring less total growth hormone to elicit insulin-antagonistic effects that are evident in the more rapidly growing line. Factors other that simple, independent concentrations of growth hormone and insulin may be of physiological significance in explaining apparent differences in nutrient uptake, utilization and growth. A similar lack of correlation between serum concentrations of hormones and various growth indices have been reported in cattle and swine. In both studies, high serum growth hormone levels were associated with slow growth rate and low ratios of carcass lean to fat. These observations together with the results of this experiment further support the contention that the simple assessment of overall concentrations of metabolic hormones and nutrients such as growth hormone, insulin and glucose ignores the possible physiological importance in the complex integration and dynamics associated with these plasma factors. This latter conclusion is even more tenable considering the interrelationships between growth hormone and insulin in rapid growth line and slow growth line gilts which are apparent from figures 1 and 2. From these expressions, the plasma relationship between growth hormone and insulin appear to be strongly related in a reciprocal fashion in both lines. The notable difference, however, between the reciprocal profiles is a more dynamic relationship which is evident in rapid growth line gilts, thereby suggesting the endocrine system of the rapid growth line may be more responsive to endocrine and metabolic stimuli than in slow growth line gilts.

The results of this experiment support the hypothesis that the mode of secretion of somatotropic hormones and the response of metabolic nutrients to changes in hormonal flux govern the rate of growth in young swine selected on the basis of growth. The nature of the interrelationhsip among plasma parameters is complex and highly integrated. Analyzing simple circulating concentrations of metabolic hormones and nutrients without recognizing modes and interrelationships of secretion may not adequately provide a basis for relating differences in the genetic potential of growth to growth-related factors. It is evident therefore that more integrated and less conventional types of sampling and analyses are warranted to more conclusively relate differences in these and other key growth factors to genetically-induced differences in growth performance.

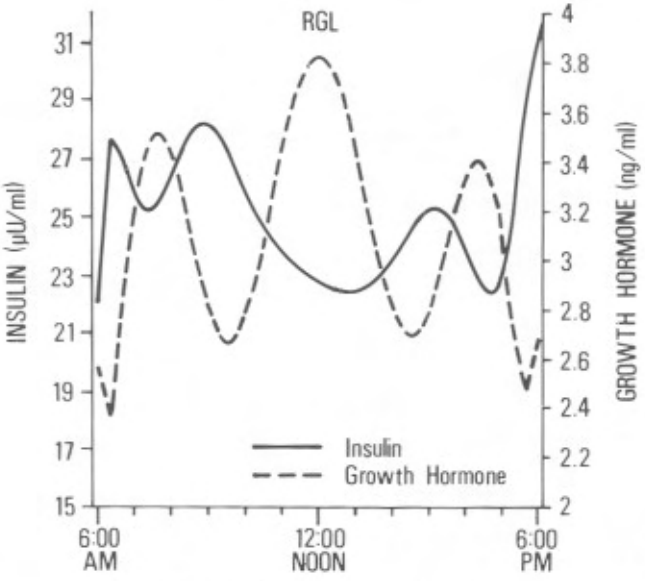

Figure 1. Illustration or the reciprocal relationship of regressed growth hormone and insulin profiles in rapid growth line gilts.

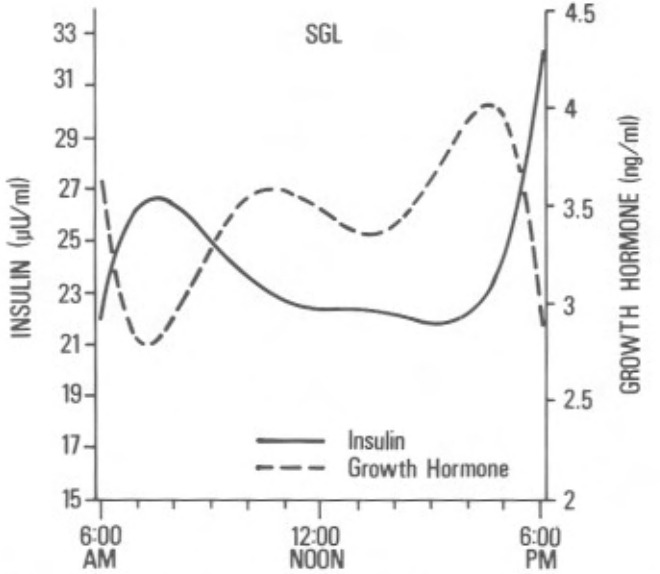

Figure 2. Illustration of the reciprocal relationship of regressed growth hormone and insulin profiles in slow growth line gilts.

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