ADVANCES IN THE MANIPULATION OF PIG GROWTH

INTERACTIONS BETWEEN PORCINE GROWTH HORMONE ADMINISTRATION AND DIETARY PROTEIN

R. G. CAMPBELL, R. J. JOHNSON, R. H. KING AND M. R. TAVERNER

SUMMARY

Two experiments involving a total of 132 entire male pigs were conducted to investigate the interrelationships between exogenous porcine growth hormone (pGH) administration (0 and 0.09mg recombinant pGH/kg/d) and dietary ideal protein levels ranging from 83 to 238 and 70 to 238g/kg on the performance and carcass composition of pigs growing from 30 to 60kg (Experiment 1) and 60 to 90kg (Experiment 2) respectively. Growth rate and feed:gain improved with increasing dietary ideal protein up to approximately 173 and 137g/kg in experiments 1 and 2 respectively and were enhanced by pGH administration in pigs offered the higher protein diets but unaffected or slightly depressed by pGH administration to pigs given the two lowest protein diets in each experiment. Protein deposition and plasma Insulin like growth factor -1 levels were similarly increased by pGH administration to pigs given the four higher protein diets in Experiment 1 but unaffected by pGH in pigs given the two lowest protein diets (83 and 114g/kg). In contrast fat deposition and carcass fat content in experiment 1 and carcass P2 fat thickness at 90kg in experiment 2 declined with increasing dietary protein and were reduced on all dietary treatments by pGH administration. These results demonstrate independent actions of GH on protein and lipid metabolism and suggest that the stimulation of protein accretion by GH is mediated via IGF-1, the release and (or) synthesis of which appears to be inhibited by dietary protein (amino acid) deficiency.

INTRODUCTION

Advances in biotechnology have provided animal scientists with a range of new materials and techniques for manipulating the growth and development of farm animals. These new technologies, which include the beta-agonists, exogenous administration of recombinant growth hormone (GH) and GH releasing hormone analogs have all proven effective to different degrees in stimulating improved growth performance and carcass quality (less fat) in pigs (Campbell etal 1988, Dubreuil etal 1988). However, by far the greatest and most consistent responses in growing pigs have been achieved by exogenous porcine GH (pGH) administration. For example Campbell etal (1989) reported that exogenous pGH administration to female pigs growing from approximately 60 - 100kg increased protein deposition 59% and reduced feed:gain and body fat content 34 and 36% respectively. Similar reductions in body fat content have been reported for pGH treated pigs by Etherton etal (1986, 1987).

Exogenous pGH administration exerts its effects on growth performance and body composition by stimulating protein deposition and inhibiting lipogenesis in muscle and adipose tissue respectively (Campbell etal 1988, Walton etal 1986, 1987). However, while the growth promoting potential of pGH therapy is unequivecol, the modes of action of the hormone remain unclear, and there is only limited information as to how the animals responsiveness to this technology might be modified by factors such as sex, genotype or nutrient intake.

Animal Research Institute, Werribee, Victoria, 3030

Campbell etal (1989) reported boars to be less responsive to exogenous pGH administration than gilts or castrated males. These authors also found that exogenous pGH administration raised protein deposition rates in the three sexes to the same absolute level and in doing so effectively eliminated the well established effects of animal sex on growth performance and body composition.

Recent studies at the Animal Research Institute, Werribee have confirmed the interaction between sex and pGH administration, but have shown that the proportional improvements in protein deposition and growth performance elicited by pGH administration are independent of genotype (R. G. Campbell, R. J. Johnson, R. H. King, and M. R. Taverner, unpublished results).

In respect to possible interrelationships between pGH administration and nutrient intake on growth performance there is evidence that the growing pigs responses to pGH administration are independent of energy intake (Campbell etal 1988). However, while the marked anabolic properties of exogenous pGH administration are related to the stimulatory effects of the hormone on protein deposition, there is no published information on the dietary protein requirements of pGH treated pigs or on the interrelationships between pGH administration and dietary protein on protein and lipid metabolism.

Because protein intake, under conditions of dietary protein deficiency is the major factor determining protein aceretion in growing pigs, such studies might also shed further light on the modes of action of GH, particularly as there is considerable debate whether the effects of GH on protein deposition and lipid metabolisn are independent or interdependent (Machlin 1972, Campbell etal 1989).

The two experiments reported here were conducted to assess the effects of exogenous pGH administration on the performance and body composition of pigs given a range of dietary "ideal" protein levels between 30 and 60kg (Experiment 1) and 60 and 90kg live weight (Experiment 2).

MATERIALS AND METHODS

Both experiments involved entire male pigs. In the first experiment 66 pigs were allocated at 30kg among an initial slaughter group comprising six animals and 12 treatments in 2 X 6 factorial arrangement. The respective factors were pGH administration (0 and 0.09mg recombinant pGH/kg/d) and dietary "ideal" protein content (83, 114, 145, 176, 207 and 238g/kg) from 30 to 60kg.

In the second experiment 66 pigs were allocated at 60kg among an initial slaughter group (six pigs) and 12 treatments in 2 X 6 factorial arrangement. The respective factors were again pGH administration (0 and 0.09mg/kg/d) and dietary "ideal" protein content (70, 103, 137, 171, 204 and 238g/kg) from 60 to 90kg.

In both experiments the pGH was administered daily by im.injection into the extensor muscles of the neck and protein and fat deposition rates were determined by comparative slaughter. Blood samples were also taken from each pig immediately before and 3 hours after the final injection of pGH or buffer solution (controls) and the plasma analysed for various metabolities and hormones including GH and insulin like growth factor 1 (IGF-1). Pigs in both experiments were also given the experimental diets in restricted

amounts based on feeding scales which provided average daily feed intakes over the experimental periods of 1.84 and 2.26kg/d in the first and second experiment respectively.

RESULTS

The results of the first experiment are summarized in Table 1. There was a significant interaction between the effects of pGH and dietary ideal protein content for growth rate, feed:gain and rate of protein deposition but not for any measure of carcass composition, linear fat thickness or rate of fat deposition. Rate of protein deposition and growth rate increased with increasing dietary ideal protein up to 175g/kg and were enhanced by pGH administration in pigs given the four higher protein diets but unaffected by pGH in pigs given the two lowest protein diets.

In contrast rate of fat deposition and carcass fat content declined with increasing dietary protein content and were reduced 21-46% on all dietary treatments by pGH administration.

TABLE 1 Effects of exogenous porcine growth hormone (PGH) administration and dietary ideal protein content between 30 and 60kg live weight on the growth performance, carcass protein and fat deposition rates and carcass fat content of entire male pigs.

pGH (mg/kg/d)	Dietary Protein (g/kg)	Daily Gain (g)	Feed:Gain	Protein (g/d)	Fat (g/d)	Carcass Fat (%)
0	83	605	3.08	72	234	31.1
	114	712	2.61	108	203	24.7
	145	776	2.36	122	210	24.2
	176	871	2.16	144	200	20.8
	207	790	2.26	146	192	22.1
	538	866	2.14	139	187	21.2
0.09	83	583	3.18	71	186	27.6
	114	750	2.47	111	175	21.9
	145	908	2.03	152	162	18.0
	176	977	1.87	166	133	15.6
	207	1007	1.81	173	123	14.7
	238	1004	1.78	174	98	13.5
Significance:						
pGH (H)		**	**	**	**	**
Dietary Protein (P)		**	**	**	*	**
H X P		**	**	**	NS	NS

NS = Not significant ($P > 0.05$); * $P < 0.05$; ** $P < 0.01$

The results for growth rate, feed:gain and carcass P2 fat thickness from the second experiment are given in Table 2.

In this experiment there was a more marked difference in the form of the response of growth performance to increasing dietary ideal protein

content between control and pGH treated pigs and the magnitude of the improvements in growth rate and feed:gain induced by pGH were proportionally larger than those achieved with the lighter body weight animals used in the first experiment. For control pigs growth performance improved with increasing dietary ideal protein content up to 137g/kg and remained constant thereafter. On the two lowest protein diets the growth performance of pGH treated pigs was slightly poorer than that of their control treated counterparts,but improved with each increase in dietary protein content up to the highest level tested (0.85g Av. lysine/MJDE). On the diet of highest protein content pGH treated pigs grew 51% faster and had a 36% lower feed:gain value compared to controls. Carcass P2 fat thickness at 90kg declined with increasing dietary "ideal" protein content and was reduced on all dietary treatments by pGH administration.

Table 2 Effects of exogenous porcine growth hormone administration and dietary ideal protein content between 60 and 90kg on the growth performance and carcass P2 fat thickness of entire male pigs.

pGH (mg/kg/d)	Dietary Protein (g/kg)	Daily Gain (g)	Feed:Gain	P2 (mm)
0	70	628	3.71	20.5
	103	803	2.86	19.8
	137	862	2.65	18.6
	171	823	2.78	20.2
	204	887	2.63	17.2
	238	860	2.71	18.4
0.09	70	588	3.87	17.0
	103	760	3.02	15.0
	137	961	2.35	12.4
	171	1108	2.07	14.2
	204	1204	1.80	14.0
	238	1338	1.69	13.1

DISCUSSION

The results provide further confirmation of the marked positive effects of exogenous pGH administration on the growth performance and carcass composition of pigs. In the first experiment pGH administration increased maximal growth rate and reduced average carcass fat content at 60kg, 17 and 23% respectively. The corresponding improvement in maximal growth rate and reduction in carcass P2 fat thickness elicited by pGH in the heavier pigs (Experiment 2) was 52 and 27% respectively.

The results showed however, that the anabolic responses induced by pGH were dependent on dietary protein content. In contrast, the effects of the hormone on lipogenesis and carcass fatness were largely independent of dietary protein. In the first experiment pGH administration increased protein deposition in pigs given the higher protein diets by 15-25% but had no effect on protein deposition in pigs given the two lowest protein diets. Rate of fat deposition in pigs given the same diets however, was reduced 14-21% by pGH. For these reasons pGH treated pigs given the two lowest protein diets exhibited-similar growth performance in Experiment 1 and poorer growth performance in Experiment 2, but were leaner than their excipient treated counterparts.

These findings provide definitive evidence of independent actions of GH on protein and lipid metabolism, and clearly demonstrate that stimulation of protein accretion by GH is not a prerequisite for its inhibitory effects on lipogenesis or vice versa.

Based on these and other data it appears that GH directly inhibits lipogenesis in adipose tissue by reducing the sensitivity of the tissue to insulin (Walton etal 1986) and by inhibiting key lipogenic enzymes (Magri etal 1987). In contrast, the stimulatory effects of GH on protein deposition in muscle tissue appear to be mediated via IGF-1, the synthesis/release of which *is* inhibited by low protein (amino acid) intake. For example in the first experiment plasma IGF-1 levels were elevated 80-90% in pGH treated pigs given the four higher protein diets, but unaffected by pGH in pigs given the two lowest protein diets (results not presented and not available for experiment 2).

From a more practical aspect the results indicate that compared to non-treated pigs the level of dietary protein required to support maximal protein deposition in pGH treated animals is related to liveweight.

For the lighter pigs (Experiment 1), pGH administration increased maximal protein deposition 23-26% but had only a marginal effect on the level of dietary protein required to support maximal protein deposition compared to controls. The similarity in the responses of excipient and pGH treated pigs to dietary protein level in this experiment suggests that in addition to stimulating protein deposition, GH also increases dietary protein utilization by improving dietary protein digestibility and (or) the efficiency of intermediatary amino acid metabolism.

In the second experiment however, there were marked differences in the responses of excipient and pGH treated pigs to dietary protein. For excipient treated pigs, growth performance increased with increasing dietary protein up to 137g/kg and remained constant thereafter. The performance of pGH treated pigs however, improved with each increase in dietary protein up to the highest level tested (0.85g available lysine/MJDE) and exceeded that of controls when both groups were given the diet containing 137g ideal protein/kg (0.63g lysine/MJDE).

Nevertheless, it is established that the growing pigs responsiveness to pGH administration increases with liveweight (Chung etal, 1985; Etherton etal 1986), and in the present experiments the maximum improvement in growth rate elicited by pGH in the heavier pigs (Experiment 2, Av. body weight = 75kg) was three fold that induced by the hormone in the pigs of lighter body weight (experiment 1, Av. body weight = 45kg).

Consequently, it's probable that the apparent improvement in dietary protein utilization induced by pGH administration is of insufficient magnitude to enable the proportionally larger increase in protein aceretion elicited by the hormone in heavier pigs to be supported without an associated increase in dietary protein (amino acid) intake. Further studies however, are required to elucidate the means by which GH might alter dietary protein (amino acid) utilization.

The practical potential of exogenous pGH administration on pig production is clearly evident from these and other published data (Campbell etal, 1988, 1989; Etherton etal 1986). Indeed the technology has 'the potential for enabling levels of growth performance to be achieved that previously would have been considered biologically impossible, and for making pork the leanest meat available to consumers.

In the shorter term, the availability of unlimited quantities of recombinant pGH and other materials such as the beta-agonists, GH releasing hormone analogs and recombinant IGF-1 provide animal scientists with an unparalleled opportunity to probe the biochemical and metabolic controls of growth and development.

Research conducted to date demonstrates that the endocrine system, and endogenous GH secretion in particular is a major factor constraining protein deposition in growing pigs. Nevertheless, the animals response to exogenous pGH administration is modified by factors such as sex, genotype, pGH dosage and protein (amino acid) intake. To fully understand the role of GH in coordinating growth and development further studies are required to determine the interrelationships between these factors and pGH administration particularly as they affect the biochemical processes involved in protein synthesis and breakdown in muscle tissue and lipogenesis and lipolysis in adipose tissue. It is hoped that such studies will identify critical control mechanisims and enable further and alternative techniques for manipulating growth and body composition to be developed.

ACKNOWLEDGEMENTS

We thank Ms. E Spiers and Messrs. W Brown, and C Reid for their expert technical assistance. Our gratitude is also extended to Dr. D Meisinger of Pitman-Moore for providing the recombinant pGH used the experiments. The financial assistance of the Pig Research Council is also acknowledged.

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