MANIPULATION OF GROWTH IN DOMESTIC ANIMALS

R.F. Thornton and R.K.Tume. CSIRO Division of Food Processing, Meat Research Laboratory, P O Box 12, CANNON HILL Q 4170, Australia.

INTRODUCTION

There is increasing interest in the efficient production of lean meat from domestic livestock. For the meat producer efficiency is measured in terms of either simple rate of production e.g. time to turn off for cattle in the pastoral regions of Australia, or food conversion and rate of production in intensively managed animal industries e.g. some temperate pasture regions of Australia, feedlots

and the pig and poultry industries in general. It is the general expectation in these intensive animal production industries that animals will grow rapidly and use less feed to achieve higher growth rates.

Apart from the economically based incentives for efficient production, the market place in general is demanding leaner i.e. less fat meat. The incentive in this area is consumer demand for leaner meat, in response to recommendations for a reduction in fat consumption. On the assumption that this trend for leaner meat will be maintained and/or continued it is clear that the numerator in the efficiency of meat production equation should be changed from carcass weight to lean meat weight. Thus the current major emphasis in research on the manipulation of growth in domestic livestock is not on growth rate per se but on the differential rates of deposition of lean (muscle) and fat (adipose tissue) in the rapidly growing animal. Such a goal is only worth achieving if the quality (in terms of flavour, tenderness, colour, texture, water holding capacity, etc.) of the meat from such animals, is highly desirable in the market place i.e. meat quality cannot be sacrificed for rapid growth rates of lean.

Growth of a tissue at the cellular level can be described in terms of hyperplasia (increase in cell number) and/or hypertrophy(increase in cell size).For many years it has been thought that the number of myoblasts (muscle cells) and the number of adipocytes (fat cells) was fixed at ,or near, birth; i.e. cellular hyperplasia was complete and further growth of these tissues was hypertrophy. This simplistic theory has been recently challenged in both muscle and adipose tissue. Muscle tissue has been shown to accumulate DNA during growth (see Dayton and Hathaway 1988) and new adipocytes (secondary hyperplasia) apparently differentiate in adipose tissue of adults (Faust et al. 1978; see Smith 1988). In cattle early postweening growth was mainly hypertrophic, between 200-350 kg liveweight growth was due to both hyperplasia and hypertrophy and above 350 kg growth was hyperplastic (Dimarco et al. 1987).

In metabolic terms growth of a tissue represents the balance of anabolic (synthetic) and catabolic (mobilisation or degradation) reactions. The emphasis is on protein metabolism in muscle and lipid metabolism in adipose tissue.

On the assumption that the efficient production of more high quality lean meat is a desirable goal, this paper considers a continuum of *existing, current* and *future technologies* that can achieve this aim. Some of these *existing technologies* are as old as the domestication of animals by man. They are common husbandry practices for lean high quality meat production in some parts of the world, and are virtually not used in other regions. Recent advances in research have produced a wide range of *current technologies* which are also in limited use today, while more recent research has uncovered *future technologies* which may be applied at some future time, provided political - economic considerations will allow their commercial deployment.

DIET

Dietary manipulation to modify growth rate and carcass composition is common practice in intensive animal production systems (both ruminant and non-ruminant) based on grain feeding. Improved ration ingredient pre-treatment and formulations have increased food conversion and growth rates. However, much of this increase is fat deposition. Achieving a reduction in fat deposition by dietary means invariably incurs a loss of growth rate and often an increased cost (Pym 1987). However, the dietary requirements, particularly of amino acids, of fast growing lean animals will require ongoing research if the genetic/economic potential of such animals is to be fully realised. At least in lambs there are isolated dietary circumstances which could be capitalised upon to produce lean meat. For instance, during early compensatory growth lambs gained a greater proportion of protein than fat (Turgeon et al. 1986). Heavy weight fat lambs in West Wales, which could not be marketed because of radioactive fallout from the Chernobyl nuclear disaster, gained carcass lean yet mobilised fat when fed protected protein supplements (Orskov, personal communication).

Current technologies such as rumen modifiers eg.monensin, are used extensively in feed lots to promote growth of cattle. Growth of ruminants has also been increased by defaunation of the rumen using chemicals and this is a *future technology* which may have commercial application (Bird and Leng 1985). Similarly genetic engineering of rumen bacteria to more efficiently digest cellulose is being researched as a *future technology* to promote growth in grazing ruminants (Gregg et al. 1987).

EXERCISE

In humans exercise is often associated with lowering of body mass and muscular hypertrophy. There are few reports of muscular hypertrophy in domestic animals that can match the extreme muscular development achieved by human male bodybuilders. Animals that are forced to exercise for draught purposes, or to walk long distances to feed and water, or during migration, are usually on less than maintenance planes of nutrition. However, applying weight to the wings of chickens induces marked growth of the anterior latissmus dorsi muscle (Laurent et al. 1978a, 1978b). Increasing the amount of added weight (110 up to 315 g) to a wing of adult hens (2.5 kg liveweight) every 2 - 4 weeks lead to a massive 4.7 times increase in weight of the anterior latissimus dorsi muscle (relative to

the unweighted wing; see Figure 1; Sparrow personal communication). Removal of the weight resulted in rapid regression of the enlarged muscle (Sparrow 1982). There seems little opportunity to commercialise this potential method of increasing muscle mass in domestic animals.

SEX

In domesticated animals and birds, females are generally fatter and grow more slowly than males, spayed females are fatter than entire females, and castrate males are fatter than entire males. In order to prevent reproduction and to facilitate management and fattening, castration and spaying are livestock management practices that have been used for centuries.

The use of entire males rather than castrates or females is an example of an *existing technology* which facilitates the production of leaner carcasses. This use of entire males has been coupled with improved nutrition to further increase growth rates which results in animals achieving an acceptable market weight prior to the onset of puberty. Thus problems of livestock management related to aggression, fertility/reproduction, of industrial agreements based on the increased difficulties of slaughtering entire males, and of detrimental attributes of meat quality associated with entire males, are avoided.

In the modern chicken broiler industry, females are identified and discarded immediately after hatching and the males are grown at such rapid rates that slaughter occurs at 6-7 weeks of age. Similar developments have occurred in the pig industry where the implementation of these existing technologies (non-castration and rapid growth) has substantially reduced, if not eliminated, the incidence of boar-taint.

The castration of male lambs, goats and calves remains a common practice in most pastoral systems. This contrasts with the poultry and pig industries and with the confined raising of sheep, goats and cattle in the northern hemisphere. However, there are notable changes, particularly in New Zealand, to castration practice. Significant economic penalties in New Zealand for over fatness in lambs has forced the producers to restrict castration. When combined with improved pasture production and management strategies, which permit lamb growth rates of 300–400g/day, ram lambs can be turned off at 3-4 months of age i.e. pre-puberty. Paddocks of mature bulls are common place in New Zealand where the farmer intends to efficiently and rapidly produce lean beef for the US market. A major problem in producing meat from entire bulls under pastoral conditions is soil erosion. Similarly in feedlots in both Australia and the USA bulls are fed for specific meat markets (notably the McDonalds hamburger chain) where the emphasis is on rapid production of lean, high water holding capacity beef. Ram lambs are being grown in Australian feedlots to produce lean heavy carcasses for the US and Middle East markets.

Reaseach has attempted to maintain the growth advantages of the male but reduce the problems associated with the management of entire males in pastoral environments. An example of such *current technology* is growth promotents and/or anabolic agents which are either sex steroids or compounds related to sex steroids. They are extensively used to promote growth in beef cattle and often result in increased lean and decreased fat deposition in the carcass meat. However, the effectiveness of these agents is largely dependant upon the sex and sexual maturity of the animals and the available plane of nutrition. Many of the anabolic agents listed in Table 1 are not registered for use in sheep and the responses of sheep to sex steroids and anabolicic agents are not as well documented as those in cattle. Their usefulness in sheep is restricted by the short duration of the fattening period for lambs. Their future use in both cattle and sheep is clouded by similiar political-regulatory considerations, that led to the banning of similar compounds in the poultry industry in the late 50's early 60's. Such regulatory consideration have not inhibited further research into the discovery and development of biological active pharmaceutical compounds, be they chemically synthesised, biologically synthesised (conventionally or by recombinant DNA techniques) or naturally occurring, e.g. growth hormone, adrenergic agonists, insulin-like growth factors etc., to promote growth in domestic animals.

Although the effects of these compounds on protein synthesis and catabolism have been well documented, little attention has been given to their effects on adipose tissue. Reduced fat deposition is often regarded as a consequence of agent-induced effects on protein metabolism rather than as a direct effect of the anabolic agent on adipose tissue metabolism (see Buttery 1985; Roche and Quirk 1986). Implantation of wethers with Revalor (52.5 mg trenbolone acetate and 7.5 mg oestradiol - β17) for 60 days resulted in reduced activities of fatty acid synthetase, acetyl-CoA-carboxylase and lipoprotein lipase (LPL) in subcutaneous adipose tissue (Burch et al. 1982). These findings indicate that both lipogenesis and incorporation of long-chain fatty acid into lipid of adipose tissue were reduced by Revalor treatment, resulting in a 20.6% reduction in trimmable carcass fat (Sulieman et al. 1981).

Some of the *future technologies* in this area relate to alternative methods of castration, e.g. chemical castration using zinc tannate or immuno-castration. Immuno-castration based on immunisation of LHRH (lutenising hormone-releasing hormone) has now been demonstrated in a range of domestic animals including bulls, rams and boars (see Schanbecker 1984; Falvo et al. 1986). In their study of boars slaughtered at 24 weeks of age and carcass weight of approximately 90 kg Falvo et al. (1986) found that LHRH immunisation decreased the incidence of boar taint but had no significant effect on growth rate or carcass attributes. Immunisation against LHRH appears to be a practical alterative to surgical castration in domestic animals.

The advantages of the male to efficiently produce lean meat (Seiedman et al. 1982) could be tempered with immunocastration of adults to reduce the management problems of males and disadvantageous characteristics of meat from males.

Some *future technologies* in this area of sexual manipulation have the possibility of superceding all

Table 1. Anabolic agents or growth promotants used in ruminants - compiled from Buttery (1985) and Roche and Quirk (1986)

Oestrogens	Androgens	Progestagens
Diethyl stilbestrol	Testosterone	Progesterone
Hexestrol	Methyl testosterone	Melengestrol
Oestradiol - 17β	Trenbolone acetate	acetate
Zeranol (resorcyclic		
acid lactone)		
Oestradiol - 17β		
benzoate		

Combined preparations
Diethyl stilbestrol + testosterone
oestadiol-17β
Zeranol + trenbolone acetate
Testosterone + oestradiol - 17β
Oestradiol - 17β + progesterone
Oestradiol - 17β + testosterone
Oestradiol - 17β + trenbolone acetate
Progesterone +

existing and current practices e.g. embryo manipulation to increase the number and/or controlling the sex of all offspring (Reviewed by Shelton, 1988). Apart from the rapid genetic advances which will result from these technologies they may also have major influences on production systems. For instance Taylor et al. (1985) have shown that in models of beef production systems the maximum efficiency of traditional systems is 2.3 to 3.5 g of lean meat per MJ of metabolisable energy (ME), which contrasts with 4.8 to 5.2 g of lean per MJ of ME for single sex once bred heifer system, i.e. an all female system, with reproduction efficiencies of 0.85 and 1.0 respectively. Other systems, e.g. all male, were only slightly better than traditional beef production systems in Taylor et al's (1985) model.

BREEDING

The long term approach to the efficient production of lean meat is obviously to breed animals with the desirable characteristics. Selection and crossbreeding programs have been employed in domestic animals but it is only in relatively recent times that the emphasis of such programs has been turned towards efficient high quality lean meat production as opposed to growth rate per se. Much of the current technology in this area relates to more precise measurement of the parameters involved in selection and crossbreeding programs. The future technology of embryo manipulation, in terms of transfer, sexing, cloning etc. has tremendous genetic and production potential, as does the advent of transgenic animals which represent the amalgamation of biotechnology and animal production in agricultural systems.

In terms of lean meat production the demonstration that mice carrying the gene for rat growth hormone grew twice as fast as litter mates and that this characteristic was passed on to the progeny (Palmiter et al. 1982) heralded the possibility of more efficient lean meat production from transgenic domestic animals. This has now been achieved in pigs (Hammer et al. 1985, Wagner 1987, Vize et al. 1988) poultry (Wagner 1987) and sheep (Hammer et al. 1985, Ward et al. 1986). Some of the earlier transgenic domestic animals with additional growth hormone genes did not grow at faster rates (Hammer et al. 1985). However, some of the transgenic pigs produced from a gene construct containing a foreign growth hormone fusion gene under the transcription control of the human metallothionein-IIA promoter, had markedly enhanced growth rates (Seamark 1987, Vize et al. 1988). Furthermore, these transgenic pigs are now in the third generation and the genotypes are being commercialised (Seamark, personal communication). There seems little doubt that animals made transgenic for growth hormone will be used for both meat and milk production in the future.

GROWTH HORMONE = SOMATOTROPHIN

The administration of exogenous and/or the manipulation of endogenous growth hormone levels to promote both milk production from cows (Bauman et al. 1985), and lean meat production from sheep and pigs, has proved outstandingly successful. However,there are few studies on the effects of growth hormone in cattle. Growth rate of 90 kg. calves was improved by about 10% in a 12 week study by Brumby (1959) but liveweight gain of 260 kg. steers was not affected in a 24 day trial (Peters 1986). In an experiment designed to study the metabolic effects of growth hormone on growing heifers, whole-body protein synthesis,and the irreversible loss and oxidation of nonesterified fatty acids, were increased by daily injections of bovine growth hormone (Eisemann etal 1986). Recently it has been reported that large framed steers had higher plasma growth hormone levels than small framed steers (Verde and Tremble 1987).

Administration of ovine growth hormone to wether lambs resulted in increased liveweight gains and protein accretion (Wagner and Veenhuizen 1978) but decreased fat deposition (Wagner and Veenhuizen 1978, Muir et al. 1983). Similarly, bovine growth hormone has been shown

Table 2 Effects of sex and exogenous porcine pituitary growth hormone(pGH) administration on the performance and carcass protein accretion rate of pigs (N=36) from 60 to 100 kg (Campbell, 1987)

Sex	Boar		Gilt		Castrate		SEM
pGH(μg/kg/d)	0	100	0	100	0	100	
Voluntary feed intake (kg/d)	3.2	3.0	3.4	2.7	3.7	2.8	0.13
Daily gain(g)	1180	1340	1011	1237	1060	1210	43.2
Feed:gain	2.7	2.2	3.3	2.2	3.5	2.30	07
Carcass fat (g/kg)	242	186	302	190	328	215	10.3
Carcass protein deposition(g/d)	164	214	133	222	128	200	9.4

to promote liveweight gain (22%), increase carcass lean (24%) and reduce carcass fat deposition (13%) in female lambs (Johnsson et al. 1985). More recently, recombinant bovine growth hormone has been shown to increase liveweight gain (30%) without significantly altering the fat or protein content of the carcasses of ram lambs (Pullar et al. 1986)

Thus growth hormone appears to be anabolic and lipolytic in sheep (see Hart and Johnsson 1986).

Although the injection of human growth hormone into pigs had no effect on growth rate (Baile et al. 1983) the treatment of growing pigs with porcine growth hormone has given significant improvements in growth rate, lean meat and food conversion efficiency (Henricson and Ulberg 1960, Macklin 1972, Chung et al. 1985, Rebhun et al. 1985, Etherton et al. 1986, Campbell 1987).

Those responses are dose dependent as illustrated by the experiment of Etherton et al. (1987) in which growth rate was improved by 14%, feed conversion efficiency by 17%, muscle mass by 19%, and carcass lipid was reduced by 25% when porcine growth hormone was injected into castrate pigs in doses of 0, 10, 30, and 70 μg/kg liveweight/day. A dose response experiment in Australia (0 to 150 ng of porcine growth hormone/kg liveweight/day) resulted in reductions in feed intake (from 2.3 to 1.8 kg/day ; 22%) and food conversion efficiency (from 2.6 to 1.8 ;31%), while daily gain increased from 0.9 to 1.1 kg/day 22% (Seamark personal communication). The data of Campbell (1987) in Table 2 illustrates the magnitude of the responses of boars, gilts and castrate males to the injection of 100 μg of porcine growth hormone/kg liveweight/day. Growth rate of the boars was a staggering 1.34 kg/day, but as Campbell (1987) pointed out carcass protein deposition rates in the treated animals were not different and ranged from 200 to 250 g/day, which may well have been the upper genetic limit of these pigs. In this study, treatment reduced carcass fat by 23%, 37% and 34% in boars, gilts and castrates respectively.

It is evident that growth hormone administration promotes a repartitioning of dietary nutrients towards stimulated growth and protein deposition in muscle and away from fat deposition in adipose tissue. The implication of these responses for lean meat production are enormous and have been stated by Cambell (1987), "This technology will enable carcass fat content to be reduced to levels not previously thought biologically possible and completely alter current concepts of energy and protein metabolism as they are influenced by sex, genotype and possibly even live weight".

However the mechanism(s) by which growth hormone exerts this repartitioning effect on muscle and adipose tissue are not clear. Growth hormone is thought to exert both direct effects on tissues and indirect effects through the stimulation of somatomedins/insulin-like growth factors in the liver and within other tissues(see Leung et al. 1987). Growth hormone has been shown to influence the in vitro differentiation of 3T3 fibroblasts to adipocytes (Nixon and Green 1983; 1984) but this has not been confirmed in vivo. In vitro experiments on sheep adipose tissue and isolated adipocytes show no direct lipolytic effect of growth hormone (see previous discussion). Similar experiments on pig adipose tissue have failed to demonstrate a direct lipolytic effect of growth hormone (Walton and Etherton 1986). This in vitro response does not mean that growth hormone is not lipolytic in vivo as it could be lipolytic indirectly (see Etherton and Walton 1986). The concept that fragments of the growth hormone molecule have biological activity not expressed by the parent molecule as well as the possibility that growth hormone enhances adipose tissue responsiveness to other lipolytic hormones have also been discussed by Etherton and Walton (1986). Summarising their own work on pig adipose tissue, and that of Vernon (1982) on sheep adipose tissue, these workers concluded" the findings suggest growth hormone antagonises insulin action" and thus glucose is diverted away from lipogenises in adipose tissue (Etherton and Walton 1986).

Similarly in vitro experiments on isolated muscles and myoblasts have shown that amino acid uptake and incorporation into protein are poorly responsive to growth hormone but are stimulated by IGF-1, one of the somatomedins or insulin-like growth factors (see Ballard et al. 1986, Dayton and Hathaway 1988). Furthermore, in pigs injection of growth hormone increases the serum levels of IGF-1 (Etherton et al. 1987, Kotts et al. 1987).

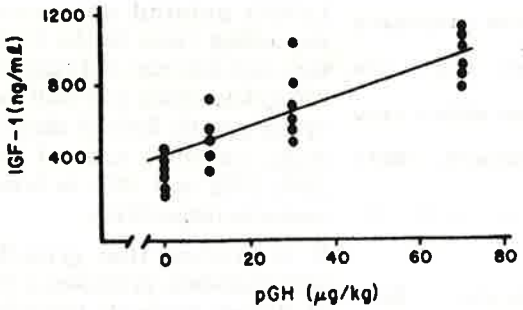

Figure 1. Effect of pGH administration on serum IGF-1 concentrations. Pigs were treated with the noted dose of pGH for 35 days. Each circle represents an individual pig (Y = 371 + 8.75X; r = .87; Etherton et al. 1987).

As injection of IGF-1 into hypophysectomised rats stimulate growth and weight gain to the same extent as growth hormone (Schoenle et al. 1982) it would appear that some of the responses of pigs injected with growth hormone can be attributed to the stimulated production of IGF-1. Recently it has been reported that the growth hormone receptors of rat adipose tissue are highly labile and require growth hormone for their maintenance (Grichting and Goodman 1986) and that growth hormone receptors of the growth plate of bone respond directly to growth hormone (Leung et al. 1987).

Production of sufficient quantities of IGFs and growth hormones, by recombinant DNA technology, for long term experiments should further delineate the respective roles of these hormones in domestic animals.

Several approaches to increasing the recombinant DNA production and the endogenous production of growth hormone and/or potentiating it's responsiveness have been investigated:
(a) Yields of >3g/L/day of recombinant methionyl porcine growth hormone in washed inclusion bodies from 1000L fermentations have been reported by Snoswell et al. (1988);
(b) The production of transgenic animals with a greater compliment of transgenic genes has been discussed above;
(c) Somatostatin immunity to promote the release of growth hormone significantly increased the growth rates of old world sheep (see Spencer 1985) but further experiments on modern commercial sheep have not been as successful (Bass et al. 1987; Laarveld et al. 1986; Hoskinson et al. 1988). None of these experiments have indicated that somatostatin immunity influenced fat deposition and somatostatin immunity seems "unpromising as a method for stimulating the growth rate of crossbred lambs" (Hoskinson et al. 1986). There have been several reports of exogenous growth hormone releasing factors enhancing growth hormone secretion in sheep (see Kensinger et al. 1987);
(d) Growth hormone releasing factor when administered to pigs promoted increased growth hormone levels and improved growth rates, feed conversion efficiency and muscle mass (Etherton et al. 1986);
(e) The activity of growth hormone has been shown to be potentiated by coupling it to a monoclonal antibody produced against it. (Aston et al. 1986);
(f) Controlled slow release implants and devices are being developed by a number of laboratories to overcome the problem of continuous daily administration of such potent lean carcass promotents.

β-ADRENERGIC AGONISTS

Some of this family of chemical analogues of the naturally occurring catecholamines have proved to have marginal positive effects on both liveweight gain and feed conversion efficiency but to be extremely potent in promoting increased lean and reduced fat deposition in the carcass meat of domestic animals (sheep, cattle, pigs and poultry). The β-adrenergic agonists are particularly effective in lambs (see Table 3).

There is now an extensive literature, on their effects on growth, feed conversion efficiency, body composition and

TABLE 3. Summary of the data from several hundred cimaterol-implanted lambs, grazing white clover perennial ryegrass pastures (Fennessy et al. personal communication).

Variable		Response (%) relative to controls and (range)
Liveweight gain (g/day)		108 (86 to 121)
Dressing percentage		2.5 (1.3 to 3.7)
Wool growth (g/day)		-16 (-27 to -6)
Heart (g)		-8 (-11 to -3)
Liver (g)		-1 (-4 to 1)
Kidney (g)		-1 (-5 to 3)
Omental fat (g)		-28 (-50 to -16)
Kidney fat (g)		-33 (-48 to -20)
Subcutaneous fat depth (mm)	GR	-27 (-43 to -10)
	C	-42 (-54 to -29)
	S1	-41 (-64 to -22)
	S2	-26 (-46 to -9)
	L3	-30 (-42 to -18)
Chemical composition of carcass		
	Water (%)	8 (4 to 11)
	Fat (%)	-22 (-33 to -15)
	Protein (%)	11 (6 to 19)
L. dorsi area (cm)		15 (5 to 25)

modes of action, which has recently been reviewed (see book by Hanrahan 1987 and reviews by Convey etal 1987; Beerman 1987; Mersmann 1987; Smith 1987; Thornton etal 1987 (a) and (b); Williams 1987). In summary, these reviews indicate that the different β-adrenergic agonists have similar gross effects on body composition in these species of domestic animals but their effects at the tissue-cellular levels are remarkably different between species. These effects are summarised in Table 4.

Some caution in interpreting this summary in Table 4 is warranted as the reported responses are from different

β-adrenergic agonists in a variety of experimental conditions. Furthermore, some of the effects are from acute experiments and are not likely to be sustained at the same levels over a long period of time (weeks/months), e.g. hind-limb blood flow in sheep infused with clenbuterol was elevated by a factor of 7 times in acute experiments (Oddy personal communication). The long term effects of β-adrenergic agonists on blood flow to both skeletal muscle and adipose tissue warrants study. Similarly plasma insulin levels rose by a factor of 4 times in lambs when they first received cimaterol (acute response) but were markedly depressed after six and twelve weeks' treatment (chronic response; Beerman 1987). In a study on pigs fed L-644,969 at 1 ppm during a seven week finishing period, weight gain and food conversion efficiency both declined linearly from 25%

TABLE 4. Summary of in vivo and in vitro responses of metabolic processes, regulatory hormones and metabolites, to β-adrenergic agonists in domestic animals.

Species	System	Process/ Hormone/ Metabolite	Response
Sheep	In vivo	Growth Hormone	Elevated
		Insulin	Reduced
		Glucose	Unchanged
		T4	Elevated
		T3	Elevated
		Prolactin	Unchanged
		NEFA	Elevated
		IGF-1	Reduced
		Cortisol	Unchanged
		Lipolysis	Stimulated
		Lipogenesis	Unchanged/ Stimulated
		Protein Synthesis	Unchanged
		Protein Degradation	Inhibited
		Hind Limb Blood Flow	Elevated
		Energy Expenditure	Increased
	In vitro	Lipolysis	Stimulated
		Lipogenesis	Inhibited
		Protein Synthesis	ND
		Protein Degradation	ND
Cattle	In vivo	Growth Hormone	Elevated
		Lipolysis	Stimulated
		Lipogenesis	Inhibited/ Unchanged
		Protein Synthesis	Stimulated
		Protein Degradation	Inhibited
		Hind Limb Blood Flow	Elevated
	In vitro	Lipolysis	ND
		Lipogenesis	Inhibited
		Protein Synthesis	ND
		Protein Degradation	ND
Pigs	In vivo	Lipolysis	Stimulated
		Lipogenesis	Inhibited/ Unchanged
		Protein Synthesis	Stimulated
		Protein Degradation	ND
	In vitro	Lipolysis	Unchanged
		Lipogenesis	Unchanged
		Protein Synthesis	Unchanged
		Protein Degradation	Unchanged
Poultry	In vivo	ND	
	In vitro	ND	

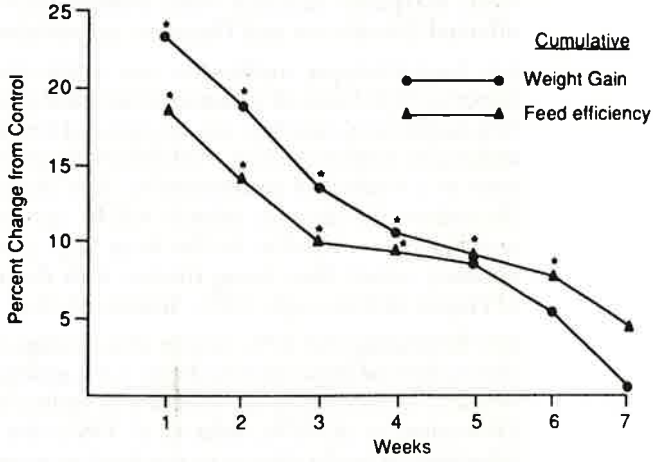

Figure 2. Cumulative weight gain and feed efficiency of pigs fed L-644,969 at 1 ppm during 7 weeks of the finishing period. Values are percent change from non-medicated controls (Convey et al. 1987).

and 20% to 5% and 1% above control levels, respectively (Convey et al. 1987; see Figure 2). These results indicate considerable adaption to β-adrenergic agonists.

We have previously suggested that the gross effects on body composition, brought about by the administration of β-adrenergic agonists, are a function of the interaction of both direct effects, on the adrenergic receptors of both skeletal muscle and adipose tissue, and indirect effects induced through changes in endocrine hormone levels (Thornton et al. 1987 (a)). It is interesting that Williams et al. (1987) have reported that the administration of both clenbuterol and bovine growth hormone had an additive effect on increasing protein deposition in calves.

IMMUNOLOGICAL CONTROL OF CARCASS COMPOSITION

Relative to drug therapy immunisation is widely accepted in the general community. There are several immunological approaches which may result in significant reductions in fat deposition and represent *future technologies.*

(a) Immuno-castration has been discussed above

(b) Regulation of endocrine hormone secretion.

Somatostatin immunity to increase growth hormone secretion has been discussed above. Although this approach has not proved successful in recent experiments the principle of immunological regulation of the hypothalamic/pituitary control of endocrine hormone production is worth pursuing e.g.

growth hormone releasing factor to increase growth hormone levels in both pigs and sheep as discussed above. This approach has been successful in regulating ovulation and lambing rates in sheep (see Scaramuzzi et al. 1987). We have immunologically targeted cortisol in sheep and although circulating cortisol levels in the treatment group were markedly reduced body composition was not affected (Hoskinson and Thornton, unpublished data).

(c) Anti-idiotypic antibodies are antibodies to the hypervariable loops of immunoglobin molecules, i.e. the first antibody is raised in one species and it is used as an antigen in another species. Anti-idiotypic antibodies are seen as a method of circumventing drug therapy is that they mimic the drug i.e. animals will be vaccinated with anti-idotypic antibodies to the drug (e.g. β-adrenergic agonist) rather than being treated with the drug (see O'Hagan and Carnegie 1987; Scarmuzzi et al. 1987).

(d) Restricting the LPL system immunologically could also reduce fat deposition in sheep. LPL activity has been blocked in chickens by the injection of antibodies to LPL (Kompiang et al. 1976; Behr et al. 1981), but repeated injections of antibodies were required to maintain LPL inhibition. The activator of LPL, apolipoprotein CII, is also likely to be suitable for immunological targeting in order to maintain reduced LPL activity. In the relatively short time required for growth of meat animals, particularly lambs, to market size, the effects of high plasma TAG are unlikely to have any serious effect on the health and welfare of the animals.

(e) Flint and co-workers (1985, 1986) have shown that when aliquots of sheep anti-rat adipocyte plasma membrane serum, or the purified antibodies, were injected into rats, there was evidence of a massive infiltration of lymphocytes into adipose tissue accompanied by a considerable breakdown of fat cells. The cytotoxic effect of the antiserum was still in evidence 2 months after the initial injections, as essentially no recovery of fat cells or growth of adipose tissue had occurred. Analyses of the carcasses at this time indicated at 30% reduction in fat content and a 5% and 7% increase in protein and water content respectively (Flint and Futter 1985).

We have repeated the experiments of Flint et al. (1986), but using horse anti-sheep adipocyte plasma membrane serum for interperitoneal injection into lambs. Using a similar protocol to that used by Flint et al. (1986), repeated injections of the γ-globulin fraction of the antiserum into sheep, failed to produce any significant reaction to fat tissue. Adipose tissue LPL was the same in control and treated animals (56 vs. 54 nmol fatty acid/min/g tissue), and plasma TAG (379 vs 370 μmol/l) were unaltered. No gross differences were observed in the carcass fat content, but there was evidence of cytotoxicity in those lambs receiving the "immune" γ-globulin, as a significant increase in plasma lactate dehydrogenase was found (0.52 vs. 0.65 μmol lactate/min/ml plasma for controls vs. treated respectively).

CONCLUSIONS

It is evident that research in the area of manipulation of growth to efficiently produce lean meat has made major advances in recent times and that equally spectacular findings are continually emerging. These exciting *further technologies* for efficient lean meat production will change the systems of meat animal production throughout the world. The individual producers, and nations, that prosper from them will be those who quickly adopt and adapt them to their local conditions and cultures.

REFERENCES

Aston, R., Holder, A.T., Preece, M.A. and Ivanyi, J. (1986). *J. of Endocrin.* **110**:381.

Bailes, C.A., Della-Fera, N.A. and McLaughlin, C.L. (1983). *Growth* **47**:225.

Ballard, F.J., Read, L.C., Francis, G.L., Bagley, C.J. and Wallace, J.C. (1986). *Biochem. J.* **233**:223

Bass, J.J., Gluckman, P.D., Fairclough, R.J., Davis, S.R. and Carter, W.D. (1987). *J. Endocr.* **112**:27.

Bauman, D.E., Eppard, P.J., De Getter, M.J. and Lanza, G.M. (1985). *J. Dairy Sci.* **68**:1352.

Behr, S.R., Patch, J.R., Forte, T., Bensadoun, A. (1981). *J. Lipid Res.* **22**:443

Beerman, D.H. (1987). Proc. 40th Rec. Meat Conf. p.57.

Bird,S.H. and Leng, R.A. (1985). *Rev. Rur. Sci.* **6**:109.

Brumby, P.J. (1959). *NZ J. Agric. Res.* **2**:683

Burch, L., Scaite, J.R. and Galbraith H. (1982). *Horm. Metabl. Res.* **14**:52.

Buttery, P.J. (1985). *Rev. Rur. Sci.* **6**:141.

Campbell R.G. (1987). Manipulating Pig Production p.85. Aust. Pig Science Association (JLF Promotions).

Chung, C.S., Etherton, T.D., and Wiggins, J.P. (1985). *J. of Anim. Sci.* **60**:118.

Convey, E.M., Rickes, E., Yang, Y.T., McElligott, M.A. and Olson, G. (1987). Proc. 40th Rec. Meat Conf. p.47.

Dayton & Hathaway (1988). Proc. 34th ICMST (This volume).

Di Marco, O.N., Baldwin, R.L. and Calvert, C.C. (1987). *J. Anim. Sci.* **65**:150.

Eisemann, J.H., Hammond, A.C., Bauman, D.E., Reynolds, P.J., McCutcheon, S.N., Tyrrell, H.F. and Haaland, G.L. (1986). *J. Nutr.* **116**:2504

Etherton, T.D., Wiggins, J.P., Evock, C.M., Chung, C.S. Rebhun. J.F., Walton, P.E. and Steele, N.C. (1987). *J. Anim. Sci.* **64**:433.

Etherton, T.D., Wiggins, J.P., Chung, C.S., Evock, C.M.,Rebhun, J.F. and Walton, P.E. (1986). *J. Anim. Sci.* **63**:1389.

Falvo, R.E., Chandrashekar, V., Arthur, R.D., Kuenstler, A.R., Hasson, T., Awoniyi, C. and Schanbacker, B.D. (1986). *J. Anim. Sci.* **63**:986

Faust, I.M., Johnson, P.R., Stern, J.S. and Hirsch. J. (1978). *Am. J. Physiol.* **235**:E279.

Flint, D.J., Coggrave, H., Futter, C.E., Garnder, M.J. and Clarke, T.J. (1986). *Int. J. Obesity* **10**:69.

Flint, D.J. and Futter, C.E., (1985). *Hannah Res. Report* p.123.

Gregg, K., Bauchop, T., Hudman, F.J., Vercoe, P., Ware, C.E., Woods, J.R. and Leng, R.A. (1983). Rec. Adv. in Anim. Nutr. p.112 (Eds. D.J. Farrell).

Grichting, G. and Goodman, H.M. (1986). *Endocriology* **119**:847.

Hammer, R.E., Pursel, V.G., Rexroad, C.E., Wall, R.J., Bolt, D.J., Ebert, K.M., Palmiter, R.D. and Brinster, R.L. (1985). *Nature* (London) **315**:680

Hanrahan, J.P. (1987). Beta-agonists and Their Effects of Animal Growth and Carcass Quality (Elsevier Applied Science).

Hart, I.C. and Johnsson I.D. (1986). Control and Manipulation of Growth p.135. Eds. P.J. Buttery, P.B. Lindsay and W.B. Haynes (Butterworths).

Henricson, B. and Ulberg, S. (1960). *J. Anim. Sci.* **19**:1002.

Hoskinson, R.M., Djura, P., Welch, R.J. and Harrison, B.E. (1986). *Proc. Aust. Soc. Anim. Prod.* **16**:415.

Hoskinson, R.M., Djura, P., Welch, R.J., Harrison, B.E., Brown, G.H. Donnelly, J.B. and Jones, M.R. (1988). *Aust. J. of Experi. Agri.* **28**:161.

Johnsson, I.D., Hart, I.C. and Butler-Hogg, B.W. (1985). *Anim. Prod.* **41**:207.

Kompiang, I.P., Bensadoun, A. and Yang, M.W.W. (1976). *J. Lipid Res.* **17**:498.

Kensigner, R.S., McMunn, L.M. Stover, R.K., Schricker, B.R., Maccecchini, M.L., Harpster, H.W. and Kavanaugh, J.F. (1987). *J. Anim. Sci.* **64**:1002.

Kotts, C.E., Buonomo, F., White, M.E., Allen, and Dayton, W.R. (1987). *J. Anim. Sci.* **64**:623.

Laarveld, B., Chaplin, R.K., Kerr, D.E. (1986). *Can. J. Anim. Sci.* **66**:77.

Laurent, G.J., Sparrow, M.P., Bates, P.C. and Millward,D.J. (1978). *Biochem. J.* **176**:419.

Laurent, G.J., Sparrow, M.P., Bates, P.C. and Millward, D.J. (1978). *Biochem. J.* **176**:393.

Leung, D.W., Spencer, S.A., Cachianes, G. Hammonds, R.G., Collins, C., Henzel, W.J., Barnard, R., Waters, M.J. and Wood, W.I. (1987). *Nature*, (London) **330**:537.

Macklin, L.J. (1972). *J. Anim. Sci.* **35**:794.

Mersmann, H.J. (1987). *Prog. Food and Nutr. Sci.* **11**:175.

Muir, L.A., Wien, S., Duquette, P.F., Ricks, E.L. and Cordes, E.H. (1983). *J. Anim. Sci.* **56**:1315.

Nixon, T. and Green, H. (1984). *Endocrinology* **114**:527

Nixon, T. and Green, H. (1983). *J. Cell. Physiol.* **115**:291

O'Hagan, R.J. and Carnegie, P.O. (1987). *Proc. Nut. Soc. Aust.* **12**:37.

Palmiter, R.E., Brinster, R.L., Hammer, R.E., Trumbauer, M.E., Rosenteld, M.G.,Birnberg, N.C. and Evans, R.M. (1982). *Nature*, (London) **300**:611

Peters, J.P. (1986). *J. Nutr.* **116**:2490

Pullar, R.A., Johnsson, I.D., Chadwick, P.M.C. and Hart, I.C. (1986). *Anim.Prodn.* **42**:433.

Pym, R.A.E. (1987). *Proc. Nat. Sco. Aust.* **12**:46.

Rebhun, J.F. Etherton, T.D., Wiggins, J.P., Chung C.S. Watton, P.E. and Steele, N. (1985). *J. Anim. Sci.* **61**:251.

Roche, J.F.and Quirk, J.F. (1986). Control and Manipluation of Growth, p.39. Ed. P.J. Buttery, D.B. Lindsay and W.B. Haynes (Butterworths).

Scaramuzzi, R.J., King, R.H. and Hoskinson, R.M. (1987). *Manipulating Pig Production* p.155. Aust. Pig Science Assoc. (JLF Promotions).

Schanbacher, B.D. (1984). *In* "Immunololgical Aspects of Reproduction in Mammals". pp.345-362. Ed. D.B. Crighton. Buterworths.

Schoenle, E., Zapt, J., Humbel, R.E. and Froesch, E.R. (1982). *Nature* **296**:252.

Seamark, R.F. (1987). Manipulating Pig Production p. 165, Aust. Pig. Sci. Assoc. (JLF Promotions)

Seideman, S.C., Cross, H.R. Ottigen, R.R. and Schanbacher, B.C. (1982). *J. Anim. Sci.* **55**:826

Shelton, J.N. (1988). *Aust. J. Biol. Sci.* **41**:In press.

Smith, S.B. (1987). Proc. 40th Rec. Meat Conf. p.65.

Smith, S.B. (1988). 34th International Congress of Meat Science and Technology, Brisbane.

Snoswell, M.A., Vize, P.D. Coles, L.S., Senn, C., Wallace, J.C. and Wells, J.R.E. (1988). *Aust. Biochem. Soc. Proc.* **20**:S83 (Abstract)

Sparrow, M.P. (1982). *Am. J. Physiol.* 242 (Cell, Physiol. 11):C333-C338.

Spencer, G.S.G. (1985). *Livestock Prod. Sci.* **12**:31.

Sulieman, A.H., Kellas, H., Galbraith, H. and Topps, J.H. (1981). *Anim. Prod.* **32**:375.

Taylor, St. C., S., Morre, A.J., Thiessen, R.B. and Bailey, C.M. (1985). *Anim. Prod.* **40**:401

Thornton, R.F., Tume, R.K., Wynn, P.C., Larsen, T.W. and Johnson, G.W. (1987a). Proc. **33** ICMST p.28 (Helsinki).

Thornton, R.F., Tume, R.K., Larsen, T.W. and Johnson, G.W. (1987b). *Proc. Nutr. Soc. Aust.* **12**:66.

Turgeon, D.A., Jr., Brink, D.A., Bartle, S.J., Klopfenstein, T.J. and Ferrell, C.L. (1986). *J. of Anim. Sci.*, **63**(3):770-780.

Verde, L.S. and Trenkle, A. (1987). *J. Anim. Sci.* **64**:426-432.

Vernon, R.G. (1982). *Int. J. Biochem.* **14**:255.

Vize, P.D., Michalska, A.E., Ashman, R., Lloyd, B., Stone, B.A., Quinn, P., Wells, J.R.E. and Seamark, R.F. (1988). *J. Cell Sci.* (In press).

Wagner, T.E. (1987). Proc. 4th AAAP Animal Science Congress p. 115

Wagner, J.F., Veenhuzen E.L. (1978) *J. Anim. Sci.* **45**:397.

Walton, P.E. and Etherton, T.D. (1986). *J. Anim. Sci.* **62**:1584-1594.

Ward, K.A., Franklin, I.R., Murray, J.D., Nancarrow, C.D., Raphael, K.A., Rigby, N.W., Brynel, C.R., Wilson, B.E. and Hunt, C.L. (1986). Proc. 3rd World Congress, Genetics Applied to Livestock Production, p.6.

Williams, P.E.V. (1987). *Nutr. Abs. Revs.* **57**:13.

Williams, P.E.V., Innes, G.M., Ogden, K. and James, S. (1987). *Anim. Prod.* **44**:475.