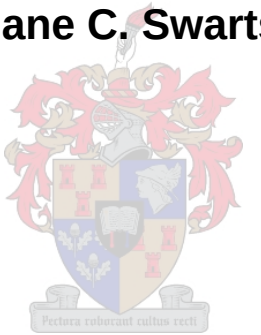
The effect of Porcine Somatotropin (pST) on production parameters, carcass and meat quality characteristics of pigs

Isane C. Swarts



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Promotor: Prof LC Hoffman

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DECLARATION

I the undersigned declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

Isane C. Swarts	1 December 2004
	Date

Summary/Abstract

Porcine somatotropin (pST) is a naturally occurring protein (hormone), secreted by the pituitary gland of young pigs and is one of the major growth regulating factors. High levels of pST is found in circulating blood of young animals, resulting in the partitioning of nutrients into lean tissue and bone growth. Supplying an exogenous source of pST should increase the deposition of lean muscle and bone and decrease the deposition of fat in the older (above 60 kg) pig. To ascertain whether pST would have a positive influence on production- and meat characteristics in the South African scenario for pigs slaughtered at a high bodymass, a trail was conducted. For group housed animals pST had no significant effect on the following parameters: feed intake, calculated cumulatively on a weekly basis, ADG, live weight, carcass weight, carcass length, ham length or chest depth, intramuscular fat area, muscle depth and colour measured with a Hennessey probe and waterbinding capacity. However, when the FCR of pigs in this investigation were calculated, there was a significant ($p<0.05$) influence by sex and pST detected. Boars converted their feed to live weight better than barrows and gilts from week ten onwards. Boars had an increased FCR when treated with pST. A significant increase was found in muscle area and a significant decrease in extra muscular (back fat) area of boars and barrows. A significant pST ($p< 0.05$) effect (3 mm reduction) was seen for backfat depth measured by the Hennessey probe and the intrascope. Porcine somatotropin significantly ($p<0.05$) increased the muscle area of the loin-cut for all animals. The area covered by subcutaneous fat of boars and barrows were significantly ($P<0.05$) reduced by pST treatment, with no effect detected for gilts ($p>0.05$). Porcine somatotropin treatment increased the muscle percentage and decreased the extramuscular fat percentage in such a way that the differences between sexes was reduced. Thus, more uniform fat-muscle distribution between carcasses was obtained by pST treatment. Control animals had a significantly higher pH_{24} than pST treated animals ($P=0.049$). Lower values were found for animals receiving pST for L* ($p=0.016$), a* ($p=0.002$) and b* ($P=0.016$). The effect on b* (yellow-blue range) in the *M longissimus thoracis* of pST treated animals showed slightly (but significantly) less yellow and more green compared to control animals ($p=0.016$). This combined with the lower L* values (brightness) indicates that pST treated animals had a significantly darker colour meat compared to the control animals. Individually housed animals showed no significant differences for the following characteristics: live weight, carcass weight, head, trotters, shoulder, middle back, middle belly, loin belly, thigh, fillet, carcass fat and kidney. Whereas pST caused a significantly lower percentage of the middle back of boars and barrows, but not in gilts, pST could only precipitate a lower percentage (11.18%) loin back of treated animals ($p=0.026$) *v.s.* control animals (12.05%). A trend ($p>0.1$) was detected for percentage bone in the middle back, with the pST treated (14.17% *vs.* 13.18%) animals having more bone than that of control animals. pST animals had a higher percentage ($p=0.024$) skin (5.04%) than the control animals (4.28%). This study shows that there is no negative effect of pST on meat quality characteristics and carcass composition, in fact there is less variation between carcasses obtained from different sexes treated with pST. The producer can bring heavier animals to the market with a reduced backfat percentage and a greater percentage meat with the help of pST.

Oorsig

Vark somatotropien (pST) is ‘n natuurlike hormoon wat deur die pituitêre klier in die brein afgeskei word by klein varkies en is een van die belangrikste hormone betrokke by groei regulering. Hoë vlakke van pST kom voor in die bloed van jong varkies, dit veroorsaak dan die verspreiding van nutriente in die liggaam van die varkie sodat dit meer vleis en beengroei toon en minder vet deponeer. Namate die varkie volwasse word neem die bloedvlakke van pST af en begin die liggam meer vet deponeer ten koste van proteien groei, terselfde tyd begin die seksuele kenmerke ontwikkel. Die toediening van ‘n eksterne bron van pST behoort die groei van been en vleis te bevoordeel in ouer diere (bo 60 kg). Vir die doeleindes van die ondersoek wou ons bepaal of pST ‘n positewe effek het op groei en vleiskwaliteitseienskappe van varke wat in Suid Afrikaanse kondisies gebruik word en teen ’n hoër liggamsmassa as gewoonlik geslag word. Vir varke wat in groepe behuis was was daar geen effek op die volgende eienskappe nie: voer inname weekliks bepaa, gemiddelde daaglikse toename, liggaamsmassa, karkasgewig, karkas lengte, ham lengte, bors diepte, intrmuskulêre vet en spierdikte bepaal met ‘n Hennessey sonde asook waterbindigs vermoë. Bere het egter ’n beter voeromsettings faktor gehat as burge en soggies, maar as pST toegedien is het hulle voeromsettingsfaktor toegeneem. ’n Betekenisvolle ($p<0.05$) toename in spier area van alle diere, met ’n gesamentlike afname in onderhuidse vet area van bere en burge (nie soggies nie) is gevind. ’n Betekenisvolle afname (3 mm) in rugvetdikte is gevind by diere wat met pST behandel is. Hierdie effekte is so in die lewe gebring dat die verskil tussen die geslagte minder prominent is en karkasse meer uniform is. Betekenisvolle hoër pH_{24} waardes is gevind by kontrole diere as by pST behandelde diere ($p=0.049$). L* ($p=0.016$), a* ($p=0.002$) en b* ($p=0.016$) waardes was betekenisvol laer vir pST behandelde diere as vir kontrole diere. Die effek op b* waardes (geel-blou reeks) in die *M. longissimus thoracis* van behandelde diere was in so ‘n mate dat die vleis ietwat minder geel en meer groen was in vergelyking met die kontrole diere ($p=0.016$), saam met laer L* waardes (helderheid) is ‘n indikasie van ietwat donkerder vleis van behandelde diere. Individueel behuisde diere het geen betekenisvolle effek getoon vir die volgende parameters nie: liggamsgewig, karkasgewig, kop, voete, skouer, middel rug, middel maag, lende maag, dy, haas en niere. ‘n Betekenisvolle laer persentasie middel rug is gevind in bere en burge, maar nie vir soggies nie, maar in die lende rug is ‘n betekenisvolle effek gevind vir alle diere (11.8% vir pST en 12.05% vir kontroe , $p=0.026$). ‘n Neiging ($p>0,1$) is gesien vir die hoeveelheid been in die middle rug van diere behandel met pST (14.17% *vs.* 13.18%) Dier met pSt behandel het’n betekenisvol hoer persentasie vel as kontrole diere gehat (5.04% *vs.* 4.28%, $p=0.024$. Die resultate van die ondersoek bewys dat daar geen negatiewe effekte van pST op vleis- en karkaseienskappe is nie, daar is self minder variasie tussen karkasse van verskillende geslagte. Die boer kan swaarder diere bemark met minder rugvet en meer vleis met behulp van pST.

"Coping with difficult people is always a problem, particularly if the difficult person happens to be oneself."

-Ashleigh Brilliant

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List of abbreviations

AAT:	Aspartate amino transferase
ADG:	Average daily gain
AMP:	Adenosine monophosphate
ARG:	Arginase
B:	Boar
bST:	Bovine somatotropin
BW:	Body weight
C:	Castrate
CLA:	Conjugated linoleic acid
CP:	Crude protein
DE:	Digestible energy
DFD:	Dry, firm and dark
DNA:	Deoxyribonucleic acid
FCR:	Feed conversion ratio
FT:	Fat thickness
G:	Gilt
GH:	Growth hormone
GHR:	Growth hormone receptor
hST:	Human somatotropin
IGF:	Insulin growth factor
IGFBP:	Insulin growth factor binding protein
LMP:	Lean meat percentage
MD:	Meat depth
mRNA:	Messenger ribonucleic acid
NEFA:	Nonesterified fatty acids
PD:	Protein deposition
pGH:	Porcine growth hormone
PSE:	Pale soft exudative
pST:	Porcine somatotropin
PUN:	Plasma urea nitrogen
RNA:	Ribonucleic acid
rpST:	Recombinant porcine somatotropin
VIA:	Video image analysis

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Chapter 1: Introduction

Biotechnology has brought many new products to the market, including some hormones, which could otherwise only be recovered form slaughtered animals. Porcine somatotropin (pST) is one of these exciting products. This has put the pork producer in the position to produce leaner animals with a better feed conversion, thus producing the meat more economically.

Hormones occur naturally in the bodies of living animals (even plants), they provide a system by which the body can effect responses in different target tissues and have a feedback system to control such a response.

Growth hormone refers to a hormone secreted from the pituitary of especially young animals to affect the processes needed to grow an immature animal to its adult size. The hormone secreted by the pig pituitary is pST and is a unique molecule specifically acting on pig tissues.

Porcine somatotropin is the most important hormone responsible for controlling the growth rate of pigs, therefore high levels of this hormone is found in the blood of young animals and the concentration decreases as the animal matures. This results in the increase of fat deposition and the decrease of protein deposition in the animal, the animal then starts developing secondary sexual characteristics.

The aim of the animal scientist in recent years has been to reduce the production of animal fats and increase the production of lean meat, since the demand for animal fats has declined drastically because of the availability of cheaper plant derived alternatives. On the other hand there is an increasing consumer demand for healthy, lean and low in cholesterol meat which has prompted the development of numerous and exciting new technologies such as administering exogenous pST to growing animals to produce meat showing these qualities.

Despite the advances made in terms of genetics, associated problems with breeding lean pigs like PSE meat etc. has slowed down the progress in breeding leaner animals. The production of recombinant porcine somatotropin (pST) has made it economically viable to produce animals leaner at higher bodyweights, with better carcass characteristics (McNamara *et al.*, 1991), or produce animals at the same bodyweights as usual with better carcass characteristics (Thiel *et al.*, 1993 and White *et al.*, 1993).

The advantages of pST treatment of animals grown to normal slaughter weights is well documented in terms of increased average daily gain, decreased backfat thickness etc. (Klindt *et al.*, 1992; Hagen *et al.*, 1991; Bidanel *et al.*, 1991; Campbell, *et al.*, 1990; Carter & Cromwell, 1998a.)

The effect of pST administration to growing pigs has been shown to decrease fat content and increase protein content (14.7% *vs.* 16.4%, Johnston *et al.*, 1993). Growth performance was also improved (ADG of 0.92 *vs.* 0.88 for pigs from 59-105 kg). This increase in growth rate resulted in the animals being ready for slaughter at an earlier age.

A number of studies investigating the influence of pST on carcass composition and carcass characteristics of animals grown up to 90- or 100 kg live weight (Thiel *et al.*, 1993; White *et al.*, 1993) have been reported, but few studies have been reported where animals were fed up to 135 kg. McNamara *et al.*

(1991) treated animals up to 136 kg and found significant effects on the reduction of fat and increase of protein in the carcasses of treated animals, but they found a low effect on bodyweight.

Etherton *et al*. (1986) and Chung *et al*. (1985) found an increase in *Longissimus* muscle area with pST treatment, but no effect on backfat thickness for animals slaughtered at the same bodyweight (below 100 kg). However, Carter and Cromwell (1998 b) found a significant decrease in backfat thickness as well as an increase in *Longissimus* muscle area of pigs treated with pST between 75 and 109 kg bodyweight.

The amount of fat and protein in meat products are not the only meat quality factors that are important. As a large portion of South African pork is sold fresh - visual appraisal plays a major role in consumer decisions when it comes to pork products. Should any meat quality characteristic have a negative impact on visual appraisal, the customer would reject such a product in favour of a more appealing product. Meat colour and the amount of exudate seeping from meat do have such an impact on visual appraisal. Visual colour, pH_1, pH_{24} and drip loss of pST treated animals have been shown not to be affected by treatment (Goodband *et al*., 1990; Ender *et al*., 1989). Decreased b* values (9.4 - 8.8) was found by Fabry *et al*. (1991), and a numerical, though non-significant, decrease in L* values, (52.9 to 51.1) was observed when they investigated the use of pST.

No South African study has been documented to ascertain whether pST treatment had an effect on the production parameters or meat quality- and carcass characteristics of pigs slaughtered at 127-135 kg live weight.

The aim of the current study was to ascertain whether pST treatment of animals used in commercial practice in the South African scenario would have a positive effect on the production parameters, carcass characteristics and pork quality of animals grown up to a bodyweight of 127 -135 kg, giving the pork producer the opportunity to produce heavier carcasses at a premium price.

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Chapter 2: Literature review

2.1. Introduction

"During the past 20 years, there have been many impressive advances in a number of scientific disciplines that have led to the discovery and development of exciting new biotechnologies that offer the potential to improve productive efficiency of animal agriculture. Some technologies have been developed from advances in our understanding of how the endocrine system regulates growth and lactation. This information has then been used to devise viable strategies to alter circulating hormone concentration(s) to enhance animal production and productive efficiency" (Etherton, 1999).

Hormones are naturally occurring messengers in the bodies of living animals, some are very specific in action and target tissues (oestrogen and progesterone), and others have a more global effect in the body (insulin). Most hormones are only secreted in response to a stimulus. Most dramatically observed in everyday life - adrenaline is released in a split second when a perceived danger is noticed.

The term "growth hormone" (GH) refers to a molecule released from the pituitary of any species of animal, including pigs. "Porcine somatotropin" (pST), refers to the specific growth hormone secreted by the pituitary of the pig (*Sus scrofa domesticus)*.

Porcine somatotropin is strongly linked with growth and development of the young pig. High levels of pST is found in circulating blood of young animals, resulting in the partitioning of nutrients into lean tissue and bone growth. As the animal matures, blood levels of pST drop and fat deposition increases, together with the development of secondary sexual characteristics (Klindt & Stone, 1984).

The aim of this review will be to discover what is known about the effects of pST in the pig, of which the most important economic factors would be the accretion of lean muscle and bone at the cost of fat accretion.

2.2. Safety

Recombinant pST (rpST) is a synthesised copy of the naturally occurring hormone, pST, found in growing pigs.

Schams *et al*. (1989) postulated that when pST is ingested orally it is denatured by gastric pH and intestinal proteases in a relatively short time span from the moment of ingestion in the manner that all protein is digested. They also mention that the chemical structure of the rpST is, with the exception of a methionine residue on the N-terminus, identical to pituitary (natural) pST. Boyd *et al.* (1988) found the natural and recombinant molecules to be identical in biological action when compared on an equal protein basis.

Porcine somatotropin (pST), human somatotropin (hST) and bovine somatotropin (bST) differ substantially from each other especially in amino acid sequence. pST and hST varies by 31% in their amino

acid sequence (Figure 1). This renders pST inactive in humans because it cannot be recognised by the hST receptor.

	10	20	30	40	50
pST	AFPAMPLSSL	FANAVLRAQH	LHQLAADTYK	EFERAYIPEG	QRYS-IQNAQA
bST	AFPAM**S**LS**G**L	FANAVLRAQH	LHQLAADT**F**K	EFER**T**YIPEG	QRYS-IQN**T**Q**V**
hST	AFP**TI**SLS**R**L	FDN**M**VLRA**HR**	LHQLA**F**DTY**Q**	EFE**E**AYIP**KE**	Q**K**YS**FL**QN**P**Q**T**
	60	70	80	90	100
pST	AFCFSETIPA	PTGKDEAQQR	SDVELLRFSL	LLIQSWLGPV	QFLSRVFTNS
bST	AFCFSETIPA	PTGKDEAQQ**K**	SD**L**ELLR**I**SL	LLIQSWLGP**L**	QFLSRVFTNS
hST	**SL**CFSE**S**IP**T**	P**SNRE**E**T**QQ**K**	S**NL**ELLR**I**SL	LLIQSWL**E**PV	QFL**RS**VF**A**NS
	110	120	130	140	150
pST	LVFGTSDR-VY	EKLKDLEEGI	QALMRELEDG	SPRAGQILKQ	TYDKFDTNLR
bST	LVFGTSDR-VY	EKLKDLEEGI	**L**ALMRELED**K**	**T**PRAGQILKQ	TYDKFDTN**M**R
hST	LV**Y**G**A**SD**SN**VY	**DL**LKDLEEGI	Q**T**LM**GR**LEDG	SPR**T**GQILKQ	TY**S**KFDTN**SH**
	160	170	180	190	191 AA's
pST	SDDALLKNYG	LLSCFKKDLH	KAETYLRVMK	CRRFVESSCA	F
bST	SDDALLKNYG	LLSCF**A**KDLH	K**T**ETYLRVMK	CRRF**G**E**A**SCA	F
hST	**N**DDALLKNYG	LL**Y**CFAKD**MD**	K**V**ET**F**LR**IVQ**	CR-**S**VE**G**SC**G**	F

Figure 1 Comparison of amino acid sequences of Human- (hST), Porcine- (pST) and Bovine (bST) somatropins (Anon, 2002).

2.3. Hormonal dynamics

2.3.1. Growth hormone (GH) and Insulin like growth factor-1

GH is secreted by the anterior pituitary, stimulating postnatal growth by stimulating mitosis in many of its target tissues (Table 1).

Table 1 The physiological effects of GH in different tissues during growth and lactation. (Etherton and Bauman, 1998).

Muscle tissue	↑ Protein accretion
	↑ Protein synthesis
	↑ Amino acid and glucose uptake
	↑ Partial efficiency of amino acid utilization
Bone (growth)	↑ Mineral accretion paralleling tissue growth
Mammary tissue (lactation)	↑ Synthesis of milk with normal composition
	↑ Uptake of nutrients for normal milk synthesis
	↑ Activity per secretory cell
	↑ Maintanance of sectretory cells
	↑ Blood flow consistent with change in milk synthesis
Adipose tissue	↓ Glucose uptake and glucose oxidation
	↓ Lipid synthesis if in positive energy balance
	↑ Basal lipolysis if in negative energy balance
	↓ Insulin stimulation of glucose metabolism and lipid synthesis
	↑ Catecholamine-stimulated lipolysis
	↑ Ability of insulin to inhibit lipolysis
	↓ GLUT4 translocation
	↓ Transcription of fatty acid synthase gene
	↓ Adipocyte hypertrophy
	↑ IGF-1 mRNA abundance
Liver	↑ Glucose output
	↓ Ability of insulin to inhibit gluconeogenesis
Intestine	↑ Absorption of calcium and phosphorus required for milk (lactation) or bone (growth)
	↑ Ability of 1,25-vitamin D3 to stimulate calcium binding protein
	↑ Calcium binding protein
Systemic effects	↑ Circulating IGF-1 and IGFBP-3
	↓ Circulating IGFBP-2
	↓ Amino acid oxidation and blood urea nitrogen
	↓ Glucose clearance
	↓ Glucose oxidation
	↓ Response to insulin tolerance test
	↑ NEFA oxidation if in negative energy balance
	↑ Cardiac output consistent with increases in milk output (lactation)
	↑ Enhanced immune response

Most importantly GH does not exert its mitosis stimulating (mitotic) effect directly on the target tissues, but does so via the mediation of a chemical messenger, stimulated by GH. This messenger is insulin like growth factor (IGF-1).

Controlled by growth hormone, IGF-1 is secreted by the liver into the blood, where it binds to a binding protein (IGFBP) and is carried to the target tissues. This renders IGF-1 as a true endocrine hormone.

IGF-1 is not only secreted by liver cells, but also other somatic cells where IGF-1 acts paracrine (acting locally) or autocrine (acting on the cell itself).

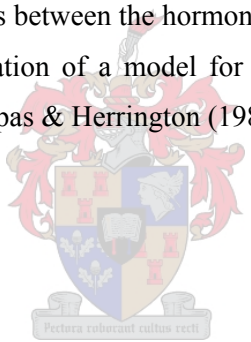
In addition to the specific growth promoting effect, by stimulating IGF-1 secretion, GH directly stimulates protein synthesis in various tissues and organs. This is achieved by causing an increase in amino acid uptake in conjunction with an increase in RNA and ribosomes, components essential for protein synthesis.

Growth hormone, in addition, has an anti-insulin effect, as insulin is essential for the uptake of glucose into cells causing the cell to have less glucose for energy production. The alternative source of energy the cell then resorts to would be fat, stimulating lypolysis (Vander *et al.* 1990).

2.3.2. The somatotropic axis

Breier (1999) did an extensive review of current literature to elucidate some of the factors involved in protein- and energy metabolism and its regulation by the somatotropic axis (relationship between the hormones controlling growth). He used three main examples: reduced nutrition, GH treatment and IGF-1 treatment to explain some of the interactions between the hormones and their receptors.

Figure 2 is a schematic representation of a model for the intracellular processing of GH and its receptor by rat adipocytes proposed by Roupas & Herrington (1989).



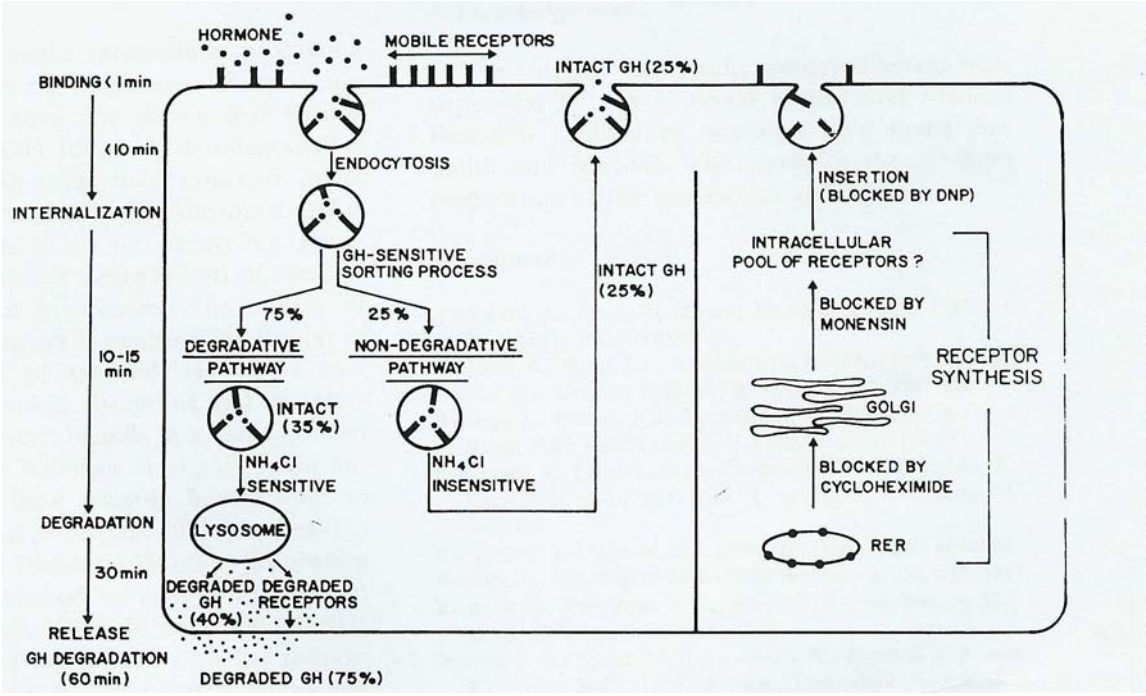


Figure 2 A schematic representation of a model for the intracellular processing of GH and its receptor by rat adipocytes proposed by Roupas & Herrington (1989).

GH secretion was found to be increased when nutritional levels were decreased, but hepatic growth hormone receptor (GHR) and plasma IGF-1 levels were reduced. IGFBP levels in plasma were also reduced by reduced nutrition (Breier, 1999).

GH treatment was found to increase protein synthesis and reduce protein degradation by modifying lipid and carbohydrate metabolism, as explained earlier. IGF-1 transcription was also found to be increased after GH administration. However, at reduced nutritional levels, it was found that there was reduced binding of GH to hepatic membranes and increased blood levels of GH. In addition, reduced blood IGF-1 levels was found, however no response was seen in the transcription of the IGF-1 gene (Breier, 1999).

Short term IGF-1 administration to yearling sheep was found to increase protein synthesis and to reduce protein breakdown. Long term IGF-1 administration, on the other hand, was found to have no effect on body weight gain or carcass composition. This can be explained by the feedback system which reduces GH secretion and hepatic GHR levels when high levels of IGF-1 prevail (Breier, 1999).

Breier (1999) concluded that the somatotropic axis has multiple levels of hormone action with complex feedback and control mechanisms acting on different levels from gene expression to regulation of mature peptide action.

2.3.3. Factors affecting circulating somatotropin levels and -receptors

Natural pST levels are strongly linked to the growth and development of the animal. Young animals have relatively high plasma levels of pST, diverting energy and protein into lean tissue growth and bone growth. As the animal mature pST levels fall, resulting in an increase in fat deposition and the development of secondary sexual characteristics to the detriment of lean tissue (muscle) deposition (Klind and Stone, 1984).

Carrol *et al.* (1998) found in early weaned pigs (2 and 3 weeks) that when post-weaning diets were changed to a lower protein and energy diet, pST levels were elevated, although growth rate and ADG (average daily gain) was affected negatively. These effects were alleviated by the bodies' compensatory mechanisms to restore normal growth when the nutritional deficit was restored.

Wray-Cahen *et al.* (1991) reported that administering (intramuscular injection) natural pST to 61 kg barrows for 28 days, at a rate of 120 mg/kg/d, resulted in plasma peaks around 4-7 hrs after injection at about five time the levels in control animals. pST concentrations returned to normal levels occurring in the control animals 18 hrs after injection. Evock *et al.* (1991) injected recombinant pST to 38 kg barrows at 0, 50 and 100 mg/kg/d for 48 days. Thirty days into the experiment pST was elevated at 3 hrs after injection in a dose related manner, returning to the baseline 10 to 14 hrs post injection.

As reported by Cochard *et al.* (1998), high dietary levels of arginine induces the release of somatotropin.

According to Yu *et al.* (2001) betaine had a dramatic increasing effect on natural somatotropin levels by up to 102.11 %, when 1 g betaine per kg feed was fed.

The complexity of regulation of pST and GHR (growth hormone receptor) was studied by Combes *et al,* (1997). They found that when feed was restricted (70 % of control) in growing pigs up to a body weight of 100 kg and pST administered, mRNA for GHR was increased in the liver, but lowered in the trapezius muscle and no effect was found on GHR mRNA levels in the longissimus muscle. This illustrates that there are definite differences in how different tissues react to growth hormone in different scenarios.

2.3.4. Effect on blood flow and -metabolites

Data obtained by Bush *et al,* (2003) suggest that blood flow in the animal is manipulated by GH: an increase in blood flow to the hind quarter of up to 80% was found; whereas blood flow to the portal drained viscera was not influenced. Growth hormone treatment influenced the uptake of phenylalanine positively in both the hind quarter and the portal drained viscera, though the effect was stronger in the hindquarter (44% *vs* 23%).

Dunshea *et al,* (1992) reported a 70 % decrease in plasma urea nitrogen (PUN) levels after only two days of pST treatment. This was probably due to an increase in the utilisation of absorbed amino acids, combined with a reduction in the breakdown of protein in muscle and liver tissue.

Krick *et al,* (1992) found a strong relationship between PUN levels and feed efficiency, confirming the effect on feed efficiency found by several other authors.

2.3.5. Pituitary and adrenal weight

Smith &Kasson (1990) found an increase in pituitary mass in conjunction with an increase in pST concentration when animals where treated with rpST. Sillence & Etherton (1989) found a significant increase in adrenal weights of animals treated with pST however the cortisol output was not influenced and blood cortisol levels remained the same as for untreated animals.

2.3.6. Dose response

As mentioned earlier the effect of GH is dependant on the level of nutrition of the animal. Since response is measured as the manifestation of effects, it is important to note other effects, like nutrition, that can affect the manifestation of these effects.

Dunshea (2002) studied the effect of administering pST on Mondays, Wednesdays and Fridays. Significant effects were obtained on FCR, backfat and a decrease in PUN was found as well as an increase in blood glucose. He concluded that although daily pST treatment resulted in the most predominant effects, intermittent treatment could serve as an alternative, provided that the intervals are not longer than 3 days, when the effect starts dissipating, this confirmed the findings of Lee *et al.* (2000).

As can be seen from Figure 3 (Etherton & Bauman 1998), different doses of pST have been shown to invoke different responses in different production parameters, i.e. feed intake, protein- / lipid- and ash accretion. These effects all have a positive impact on production as well as meat characteristics.

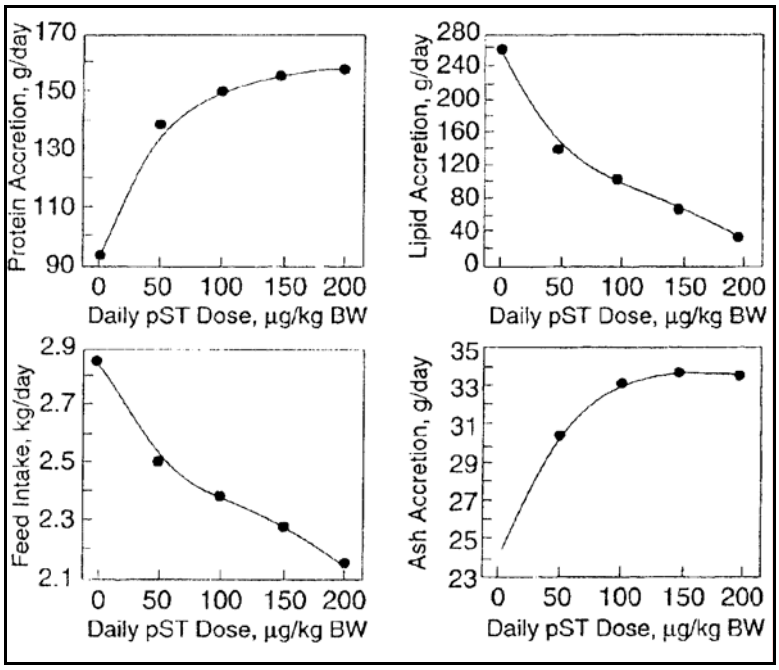


Figure 3 Relationship between pST dose and different parameters of growth and performance (Etherton & Bauman, 1998)

2.4. Growth and metabolism

2.4.1. Protein accretion and lean tissue deposition

Since protein accretion and amino acid accretion is very closely associated (protein accretion is impossible without amino acid accretion), it can be accepted (especially with limiting amino acids) that the two are the same for the purposes of this study.

It is important to note the tissue specificity of the effect of GH in the animal; as studied by Bush *et al.* (2003), finding differential blood flow to different tissues, as well as different protein accretion rates in different tissues of treated animals. In earlier studies Bush *et al.* (2002) found that amino acid catabolism was reduced by reduced hepatic urea cycle enzyme activities. This effect on urea cycle enzymes is tissue specific and correlated to a reduction in substrate availability for hepatic ureagenesis.

Roy *et al.* (2000) & Vann *et al.* (2000) provided data supporting that pST administration of well nourished pigs increased protein accretion by suppression of protein degradation, rather than the increase of protein synthesis. This was done by proving that whole body leucine appearance was decreased, as well as leucine oxidation and urea production whereas nonoxidative leucine disposal was increased. Tissue protein synthesis was, however, not affected. This was confirmed by Lee *et al.* (1999), who found that pST not only improved nitrogen retention, but also improved the efficiency of utilisation of apparently absorbed nitrogen in growing pigs (above 60 kg). This was shown in diets having the potential for low - or high efficiencies of nitrogen utilisation (48 *vs* 62 %).

Increases in dietary CP (crude protein) level was shown to increase liver arginase (ARG)- and aspartate amino transferase (AAT) activities, whereas dietary energy had no impact on their activities, thus increased breakdown of protein is anticipated. GH treatment was shown to decrease serum urea, AAT- and ARG activities. However, effects of GH treatment was not found to induce an expression of a statistical interaction between dietary protein and liver ARG- and AAT activities (Rosebrough *et al.* 1998), suggesting that pST effects are independent of set nutritional states (between 110- and 270g/kg dietary protein in the diet).

King *et al.* (2000) concluded that the increase in lysine requirement when pST is fed is as a result of the increased levels of protein deposition induced by pST.

These contradictory theories prove that the mechanism of action and reason for the increased protein demand has not been resolved fully yet.

2.4.2. Adipose tissue response and fat deposition

In a review by Etherton & Bauman (1998) it is postulated that GH does not reduce the ability of insulin to inhibit lypolysis in adipose tissue or stimulate the rate of protein synthesis in adipose tissue, or stimulate glucose uptake and muscle protein synthesis. Therefore GH does not cause a true insulin tolerant condition, but it modulates tissue responsiveness to insulin. This renders the action of insulin to be specific in these tissues, partitioning nutrients (glucose) specifically to muscle and bone to support growth, and reduces the amount of glucose available for lypogenesis. Bergen (2001) supports this theory that the response to GH observed in reduced fat deposition is mainly due to a reduced rate of deposition and not an increase in lypolysis.

Dunshea *et al.* (2002) found a reduction in backfat of 3.2 mm in gilts and 2.3 mm in boars treated with 5 mg pST per day from 70 kg body weight.

Ramsey *et al.* (2001) studied the effect of CLA (conjugated linoleic acid) and pST on the reduction in carcass lipid content. They found no synergistic effect on carcass fat content. Porcine somatotropin alone increased levels of polyunsaturated fatty acids in latissimus adipose tissue and reduced levels of saturated fatty acids in pigs fed CLA.

A review by Nurnburg *et al.* (1998) emphasises the fact that there is a positive correlation between the amount of fatty tissue deposited and the fatty acid content of such tissue.

2.4.3. Impact of temperature on pST response

Van der Hel *et al.* (1997) showed that submitting pigs treated with pST to varying ambient temperatures by stepping down daily from 23 to 8°C and then up from 8 to 23°C with 3°C intervals per day had no significant effect on metabolic responses to pST. Heat production was, however, increased by 65 $kJ/kg^{0.75}$ daily and maintenance requirement by 75 $kJ/kg^{0.75}$ daily, high feeding levels increased heat production (+97 $kJ/kg^{0.75}$) and energy retention (+220 $kJ/kg^{0.75}$ daily).

2.4.4. Effects on reproductive performance

Treating 73 kg gilts with 5 mg pST for 30 days, followed by a 21 day withdrawal, had no effect on reproductive performance. Measurements where taken on development of ovaries, estrual cyclicity as well as ovulatory rates and no difference between treated and untreated animals where found by Bryan *et al.* (1989).

Fiedler *et al.* (1996) showed that treating pregnant sows with pST increased the weight of the thyroid glands of piglets by 4.8% compared to controls, but only in sows' piglets who received treatment in the last term of pregnancy. This treatment did not have any effect on adrenal weights of the piglets, but the nuclei of medullar cells were bigger and the cortex was reduced in thickness. Serum glucose levels were increased in the piglets, showing an effect of pST on the metabolism, even at this age.

Kuhn *et al.* (2004) found no effect on birth weight of piglets born to sows treated in early pregnancy with pST. However, these piglets' meat quality characteristics was influenced by increased drip losses and pH changes, towards pale, soft, exudative (PSE) meat.

2.4.5. Organ and skin growth

Evock *et al.* (1991) found the following effects when treating barrows from 38 kg body weight with varying levels of pST (0, 50 and 100 g per day) as tabulated in Table 2. They found increased weights of the liver, heart and kidneys of animals treated with pST. Response was also shown to be dose dependant where these organs increased in weight with increases in dose up to 100 g pST per day.

Table 2: Effect of somatotropin treatment (from 38 kg body weight) on selected organ weights as % of total body weight (Evock *et al.*, 1991).

Organ	**0 µg pST daily**	**50 µg pST daily**	**100 µg pST daily**
Heart	0.322	0.380	0.394
Liver	1.47	1.94	2.04
Kidneys	0.308	0.404	0.455

Caperna *et al.* (1994) concluded, from a study on barrows treated with pST from 30 kg body weight to 64 kg body weight, that protein deposition was increased in skin and viscera as well as muscle and bone, but the effects was more accentuated in muscle and bone.

2.5. Influences on production

2.5.1. Improved feed efficiency and voluntary feed intake

Klindt *et a.l* (1992) found a reduction in feed intake, but no effect on ADG in barrows and gilts treated with various levels of pST. Whereas Klindt *et al.* (1995), in a later report, found a reduction in feed intake of boars and gilts treated with various levels of pST, as well as a significant increase in daily gain.

Dunshea *et al.* (2002) found, with a 5 mg per day pST treatment, a reduction in voluntary feed intake of 10% in barrows and gilts. This reduction in feed intake combined with the increased efficiency of protein utilisation is the major factors resulting in decreased FCR seen in pST treated animals.

Wray-Cahen *et al.* (1991) found an increase in dry matter digestibility of up to 5% when pST was administered. Van Weerden *et al.* (1990) found a decrease in nitrogen excretion. This indicates that the treated animals where significantly more efficient in utilising dietary nitrogen for protein deposition. Furthermore, it was found in the same study that treated animals excreted 16% less phosphorous, indicating that they were also more efficient in utilising dietary phosphorous for bone development.

Table 3 Effect of pST on ADG in gilts, boars and barrows.

		ADG change			
Start weight	**pST level**	**Gilts**	**Barrows**	**Boars**	**Reference**
70 kg	5 mg/d	↑ 23 %	Not studied	↑ 2.5 %	Dunshea *et al.* (2002)
60 kg	100 µg/kg BW	Not studied.	↑ 13-20%	Not studied.	Evock *et al.* (1991)
80 & 50	8 mg/2 days	Not studied	↑ 11.6%	Not studied.	Kim *et al.* (1998)

Table 3 & 4 show results obtained from different studies, showing increases in ADG in gilts, barrows and boars with the effects being definitely more pronounced in gilts treated with pST. The decrease in FCR however, is much more sex type dependant, where a low to no effect was found in boars, wilst a 23% decrease in barrows was noted.

Table 4 Effect of pST on FCR in gilts, boars ands barrows.

		FCR change			
Start weight	**pST level**	**Gilts**	**Barrows**	**Boars**	**Reference**
70 kg	5 mg/d	↓	Not studied	No effect	Dunshea *et al.* (2002)
60 kg	100 µg/kg BW	Not studied.	↓ 17-23%	Not studied	Evock *et al.* (1991)
80 & 50	8 mg/2 days	Not studied.	↓11.2-21.9%	Not studied.	Kim *et al.*, (1998)

King *et al.* (2000) provided evidence that pST treatment decreased the difference in FCR observed between sexes. They also found that the nutritional requirements for optimum growth rate and FCR were significantly different for control and pST treated animals (between 80 and 120 kg). For control animals (irrespective of sex) 0.35 g lysine/MJ DE was sufficient for optimum growth rate and FCR, whereas the pST treated animals could only achieve maximum growth and FCR at a dietary lysine level of 0.52g lysine/MJ DE.

Even during a severe endotoxin challenge, pST was effective in inducing a positive effect on feed to gain ratio and ADG, although feed efficiency was impaired and variable (Evock *et al.*, 1991).

2.6. Effect on meat- and processing characteristics

2.6.1. Muscle characteristics

Solomon *et al.* (1990) showed that pST treatment in pigs resulted in an increase of *Longissimus* muscle fiber size for gilts, boars and barrows. The magnitude of the effect differed, where barrows (31.8%) had the largest response, followed by gilts (27.7%) and boars (9.3%) in pigs grown from 50 kg to 90 kg. In 1994, Solomon *et al.* reported on the negative effect marginal dietary protein had on the effect of pST on pigs, causing a reduction in the rate of muscle fiber growth.

2.6.2. Meat quality

Numerous studies indicated that pST treatment (3-6mg/d) had no effect on pork muscle tenderness, flavour, juiciness, colour, cooking loss, firmness and pH, they were, however, not able to prove any effect (Beerman *et al.* 1990; Boles *et al.* 1991; Dugan *et al.* 1997; Ender *et al.* 1989; Fabry *et al.* 1991; Gardner *et al.* 1990; Goodband *et al.* 1993; Hagen *et al.* 1991; Johnston *et al.* 1993; McPhee *et al.* 1991; Mourot *et al.* 1992; Prusa, *et al.* 1990 & Solomon *et al.* 1994).

Jeremiah *et al.* (1998) however found that a 2 mg/day treatment improved ham and loin tenderness above those of control animals.

Dugan *et al.* (1997) found a sex by pST treatment interaction for loin depth, moisture content, colour score, light reflectance, picnic lean, ham lean and carcass lean yield; which indicated that barrows responded more favourably to pST treatment than gilts. Mourot *et al.* (1992) found a decrease in intramuscular fat, and an increase in the percentage polyunsaturated fat of pST treated animals.

2.6.3. Carcass characteristics

Carcasses of pST treated animals were found to contain less fat and more meat, with a thinner backfat layer (Smith & Kasson, 1990).

2.6.4. Processing characteristics

Bryan *et al.* (1989) manufactured frankfurters from the New York shoulders of pST (5 mg per day) treated gilts, they formulated the frankfurters to contain 22% fat from the same carcass and 10% added water. Frankfurters from pST treated gilts had a greater smokehouse loss than control frankfurters (0.9%), but a greater shear force peak height (35.4%). This increase in force needed for skin failure could not be explained by other differences due to treatment (cooking stability, batter proximate composition or salt soluble protein content), other than pST treatment causing a higher loss in water and causing tougher frankfurters.

2.7. Nutrition

2.7.1. Protein/lysine

It is absolutely imperative for pST treated animals to have an adequate intake of protein, energy, vitamins and minerals. Etherton & Bauman (1998) postulated that the increased protein deposition of the pST treated animals was due to an increase in the efficiency of utilisation of dietary protein and/ or an increase in requirement for dietary protein to support the increased protein deposition.

Campbell *et al.* (1991) found no effect on protein utilisation of pST treatment from 60 kg to 90 kg in genetically improved boars. This effect is probably due to the high efficiency of utilisation by the control animals (and treated animals) of 62%, from the onset. However, the requirement for protein in the diet increased from 11 to 18% to support an increase in protein deposition from 119 to 215 g per day (Figure 4). This study reported that no benefit was obtained from using pST in animals fed a low protein content diet. Overall growth performance was reduced due to a decrease in fat deposition, suggesting that animals with the potential to perform at very high levels should have an increased dietary protein intake to sustain these high levels of protein deposition.

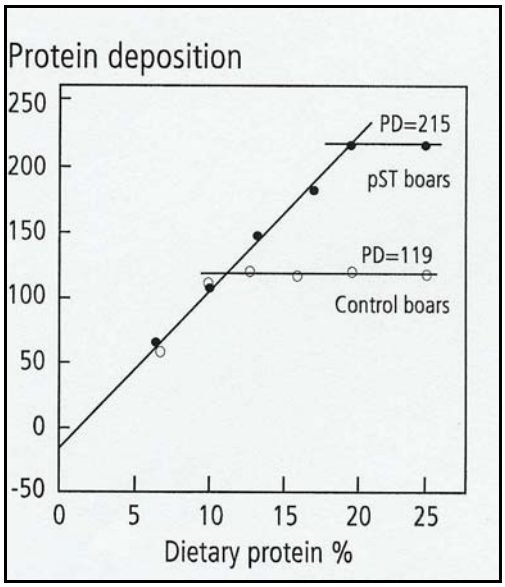


Figure 4 Effect of dietary protein content on the rate of protein deposition (Campbell *et al.* 1991).

In the same study by Campbell *et al.* (1991) a strong relationship between dietary protein level and rate of protein deposition was found in treated and untreated boars (Figure 4) but the effect was definitely more dramatic in animals treated with pST. All animals treated with pST had a significantly lower rate of fat deposition than animals not treated with pST. At a dietary protein level of 23.5% the fat reduction effect was still measurable, but below 19% protein in the diet the effect became minimal, i.e. the response curve started levelling off (Figure 5).

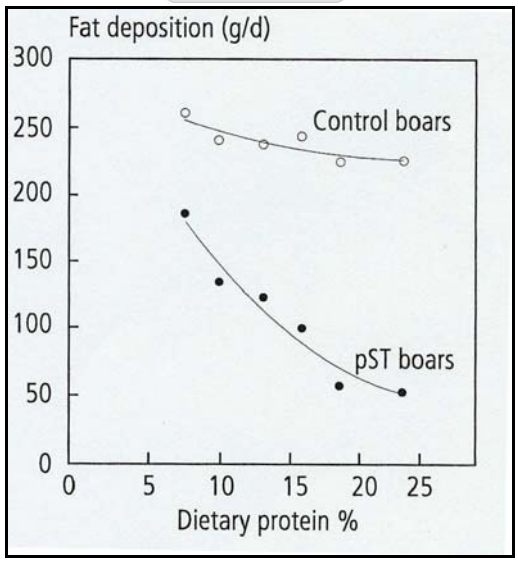


Figure 5 Effect of dietary protein on the rate of fat deposition (Campbell *et al.* 1991).

Goodband *et al.* (1990) found a strong relationship between average daily gain (ADG) and dietary lysine levels for pST treated barrows and boars (Figure 6). Maximum ADG was attained at a 1.2% lysine in the diet equating to 30.7g lysine intake per day.

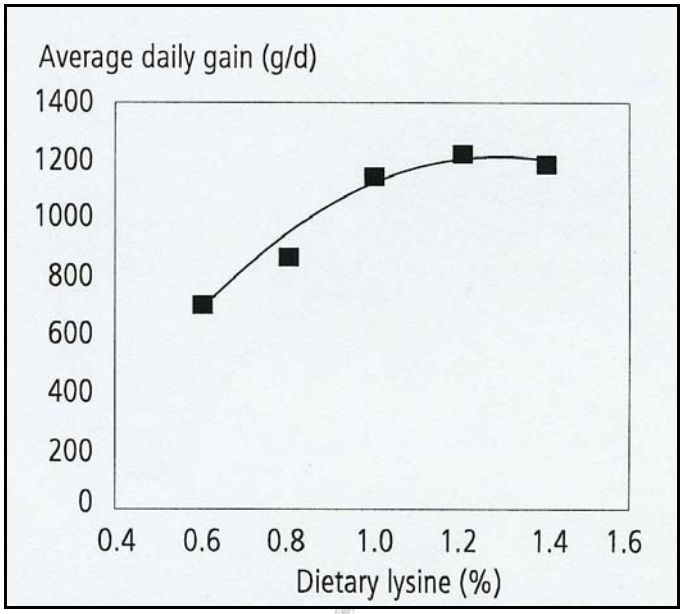


Figure 6 The relationship between pST treatment (4 mg per day) and dietary lysine levels on daily weight gain of barrows and gilts from 60-95 kg body weight (Goodband *et al.* 1990).

This study also revealed a strong relationship between dietary lysine levels and FCR of animals treated with pST (Figure 7). With an increase in dietary lysine from 0.6% to 1.2%, feed: gain ratio for pST treated barrows and gilts was decreased from 3.12 to 1.96 kg feed eaten per kg weight gained. Lysine levels greater than 1.0% did not have a significant decreasing effect on FCR.

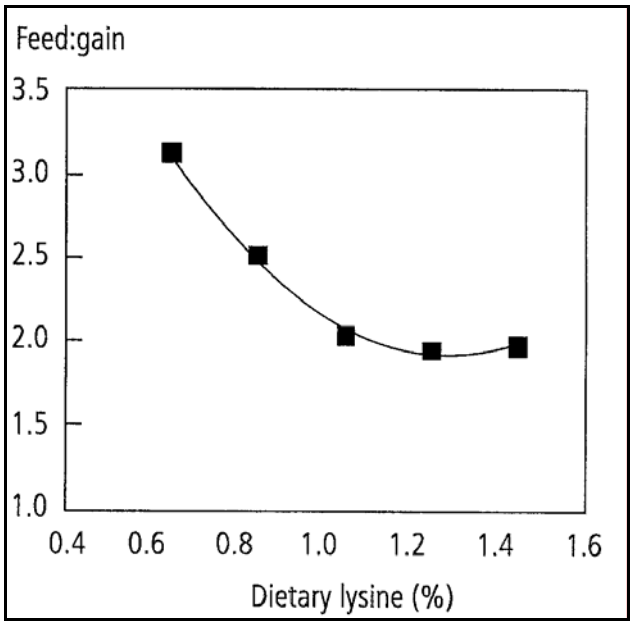


Figure 7 The effect of pST treatment (4 mg per day) and dietary lysine level on feed: gain ratio of barrows and gilts from 60-95 kg body weight (Goodband *et al.* 1990).

Jewell & Knight (1991) found that (in support of data obtained with increased dietary protein) increased levels of dietary lysine had a reducing effect on carcass fat when pST was administered (3mg per day). This effect was at its maximum (25.3% reduction in carcass fat) when the diet contained 1.25 % lysine.

2.7.2. Energy

Campbell *et al.* (1991) found a linear-plateau relationship between energy intake and protein deposition for boars and gilts treated with pST (6 mg per day) from 60-90 kg body weight (Figure 8).

Protein deposition in pST treated gilts reached a plateau of 203g per day at a daily energy intake of 34 MJ. In this study boars did not reach a plateau in protein deposition, even at an energy intake of 43 MJ per day, they were accruing 249g protein per day. At increasing levels of energy in the diet, the percentage fat in the carcass increases, the difference between control animals and pST treated animals are, however maintained (Figure 8).

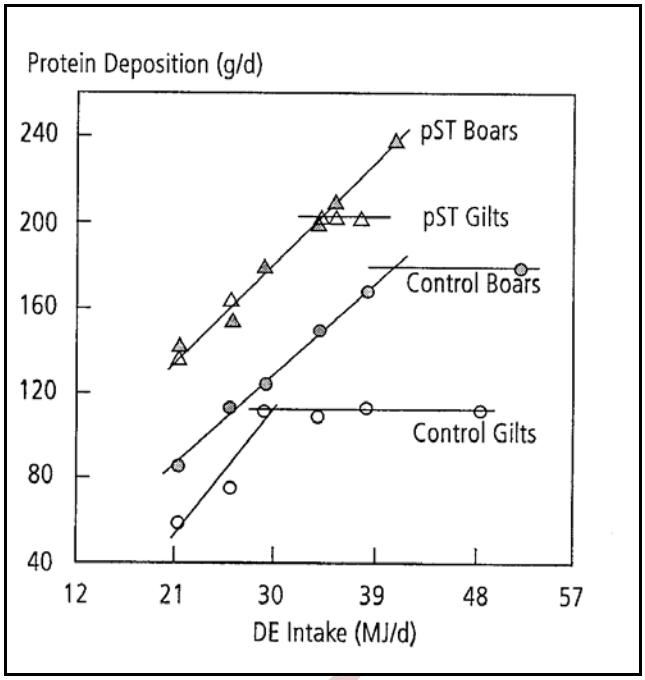


Figure 8 Relationship between digestible energy intake and protein deposition capacity for control and pST – treated gilts and boars (Campbell *et al.*, 1991)

Furthermore it was found in this study by Campbell *et al.* (1991) that there was a strong relationship between dietary energy levels and feed to gain ratio in pST treated animals. Porcine somatotropin treatment resulted in a decrease in feed to gain ratio at all levels of dietary energy intake. They found that levels above 34 MJ per day increased the feed to gain ratio of the control boars and pST treated gilts slightly. However, pST treatment had a decreasing effect on the feed to gain ratio in boar up to a daily energy intake of 39 MJ, where a plateau was reached (Figure 9).

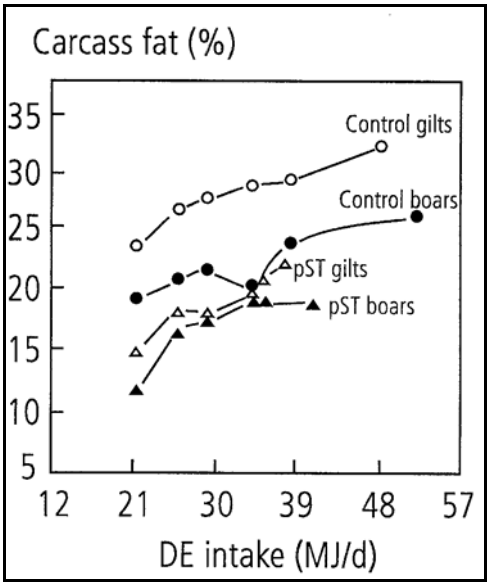


Figure 9 Effect of energy intake and exogenous pST administration on the carcass fat content of female and male pigs treated from 60-90 kg body weight (Campbell *et al.* 1991).

2.7.3. Calcium and phosphorus

Carter & Cromwell (1998 a,b) found that 4mg pST treated animals needed 15-20g of dietary phosphorous daily to maintain maximum protein deposition and minimum fat accretion, without a negative effect on bone mineralisation.

2.8. Conclusion

The advantages shown in terms of growth on FCR could give the pork producer an advantage above his competitors not using pST as well as better quality carcasses, with less backfat.

It is however important to remember that the management of pST treated animals is different as pST treated animals have to be fed a higher concentration protein.

The aim of the current study was to measure the effects of pST on the production and meat quality characteristics, as well as tissue yield of animals grown between 127 kg and 135 kg in the South African scenario.

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Chapter 3: The influence of porcine somatatropin (pST) on production parameters and tissue yield of pigs slaughtered at 135 kg live weight

3.1. Abstract

Eighteen F1 crossbred (commercial type terminal crosses) pigs (boars, barrows and gilts) with an initial weight of 27.2 ± 2 kg were used to investigate the effect of porcine somatotropin (pST) administered for 6 weeks prior to slaughter on production parameters in the South African scenario. Pigs were grown to 135 kg live weight which is heavier than the average 70- 90 kg weight of slaughter in South Africa. Porcine somatotropin had no significant effect on average daily gain or feed intake. However, pST administration caused a significant increase in FCR (kg feed / kg gain) of treated boars, indicating that boars converted their feed less efficiently when treated with pST, contradicting most of the findings in the literature. The effect of pST on the different carcass cuts were not significant, except for the percentage loin back, which was higher for pST treated animals and percentage middle back of boars and barrows, which was slightly higher. No significant pST effects were found for live weight, carcass weight, % bone, % fat or % lean meat, but a significant increase in percentage skin was found.

Keywords: FCR, P2 backfat, pST, tissue yield, pork

3.2. Introduction

The production of acceptable animal derived products in a sustainable manner has been the aim of farmers since they started domesticating meat animals. The emphasis has, however changed as consumer demands have changed from people who do physical labour to health conscious consumers demanding low fat, healthy food. Therefore in recent times, the consumption of leaner meat has become the norm.

Despite the advances made in terms of genetics, associated problems with breeding lean pigs like PSE meat etc. has slowed down the progress in breeding leaner animals. The production of recombinant porcine somatotropin (pST) has made it economically viable to produce leaner animals at higher bodyweights, with better carcass characteristics (McNamara *et al.*, 1991), or produce animals at similar bodyweights with better carcass characteristics (Thiel *et al.*, 1993 & White *et al.*, 1993).

The advantages of pST treatment of animals grown to normal slaughter weights (90 kg) is well documented in terms of increased average daily gain, decreased backfat thickness etc. (Klindt *et al.*, 1992; Klindt *et al.*, 1995; Hagen *et al.*, 1991; Bidanel *et al.*, 1991; Campbell, *et al.*, 1990; Carter & Cromwell, 1998).

A number of studies investigating the influence of pST on carcass composition and carcass characteristics of animals grown up to 90 or 100 kg live weight (Thiel *et al.*, 1993 & White *et al.*, 1993) have been reported, but few studies have been reported where animals were fed up to 135 kg. McNamara *et al.* (1991) treated animals up to 136 kg and found significant effects on the reduction of fat and increase of protein in the carcasses of treated animals, but they found a low effect on bodyweight.

The aim of the current study was to ascertain whether pST treatment of animals used in commercial production in the South African scenario would have a positive effect on the performance and tissue yield (composition) of animals grown up to a bodyweight of 135 kg. Carcasses were divided into commercial cuts which were dissected to ascertain how the distribution of body tissue is influenced by pST treatment as has been noted previously (Thiel, *et al.*, 1993, White *et al.*, 1993 & Fabry *et al.*, 1991, etc.). The effect of the sex type of the treated animals was also studied on all these parameters.

3.3. Materials and methods

Eighteen crossbred animals (commercial type terminal crosses) housed in individual pens were used. Animals were equally divided into three sex types: boars, gilts and barrows. The trial started with animals of 9-10 weeks of age, weighing 27.2 ± 2 kg.

Pens were equipped with a self feeder and automatic water nipple. The facilities comprised of a commercial type grower house with temperature control *via* automatically opening curtains.

Porcine somatotropin was administered to animals randomly allocated to the pST treatment group after they reached an average bodyweight of 95 kg. A daily dose of 1 ml (5 mg rpST) reconstituted Reporcin® (Alpharma Animal Health, Victoria, Australia) was administered intramuscularly at the base of the neck for 6 weeks prior to slaughter.

A commercial grower diet (Diet 1, Table 1) containing 18 % crude protein (CP), 1.1 % lysine, 14 MJ/kg digestible energy and oxytetracycline (10%) (included at 2 kg/ton) was fed for the first 14 days after arrival. Thereafter Diet 2 was fed until 6 weeks into the trail, when animals attained an average live weight of c.a. 65 kg. Diet 2 had the same composition as Diet 1, but contained no medication.

Diet 3, containing 16 % crude protein, 0.9 % lysine and 13.5 MJ/kg digestible energy was then fed to all the animals from 6 to 12 weeks into the trail (average live weight *ca.* 95 kg).

It is well documented that voluntary feed intake of pST treated pigs decrease significantly (Kanis *et al*. 1990; Johnston *et al*. 1993). To ensure that the control- and pST treated groups had similar total protein (lysine) intakes, a diet with a higher concentration protein was fed to the pST treated groups. Thus, when administration of pST commenced at 12 weeks the pST treated animals was fed an 18 % CP diet (Diet 2) until the end of the trail. The control animals remained on Diet 3 (16 % CP). All animals had *ad libitum* access to the feed.

Table 1 Ingredient and nutrient composition (g/kg) of diets fed to pigs

Ingredient	Diet 1	Diet 2	Diet 3
Yellow maize	689.7	688.2	674.4
Soya bean oilcake meal (47% CP)	116.1	127.3	118.6
Sunflower oilcake meal (38% CP)	33.8	32.0	113.0
Fishmeal (65% CP)	79.9	72.9	-
Wheaten bran	50.0	50.0	50.0
Synthetic lysine	9.0	9.0	3.2
Synthetic methionine	-	-	4.0
Synthetic threonine	-	-	8.0
Monocalcium phosphate	9.4	10.1	16.8
Feed lime	11.8	12.0	14.9
Fine salt	2.4	2.6	3.9
Vitamin & Mineral premix	4.0	4.0	4.0
Oxitetracycline (10%)	2.0	-	-
[1]DE MJ/kg	14	14	13.5
[1]Lysine	11	9	9

[1]Calculated from analysed raw materials

Feed intake and animal weights were measured weekly. The data was then used to calculate a FCR by dividing the total feed intake by the total body mass gain of the animals during the trail period. Average daily gain was analysed by fitting a linear model.

Animals were slaughtered after 15 weeks in this investigation, at an average live weight of 135 kg in a commercial abattoir. Animals were transported and handled in a calm manner until slaughter. Due to the vehicle - design, animals had to be mixed during transport and in the holding pens at the abattoir.

Animals were led into a stunning cage where they were stunned with an electrical stunner set at 220V and 1.8A, with a current flow of no longer than six seconds. Electrodes were placed at the base of the ear. Within 10 seconds exsanguination followed, and within 50 seconds shackling and hoisting of the carcass was completed. Scalding commenced within 5 minutes after stunning. Thereafter the carcasses were dressed using the standard commercial procedures.

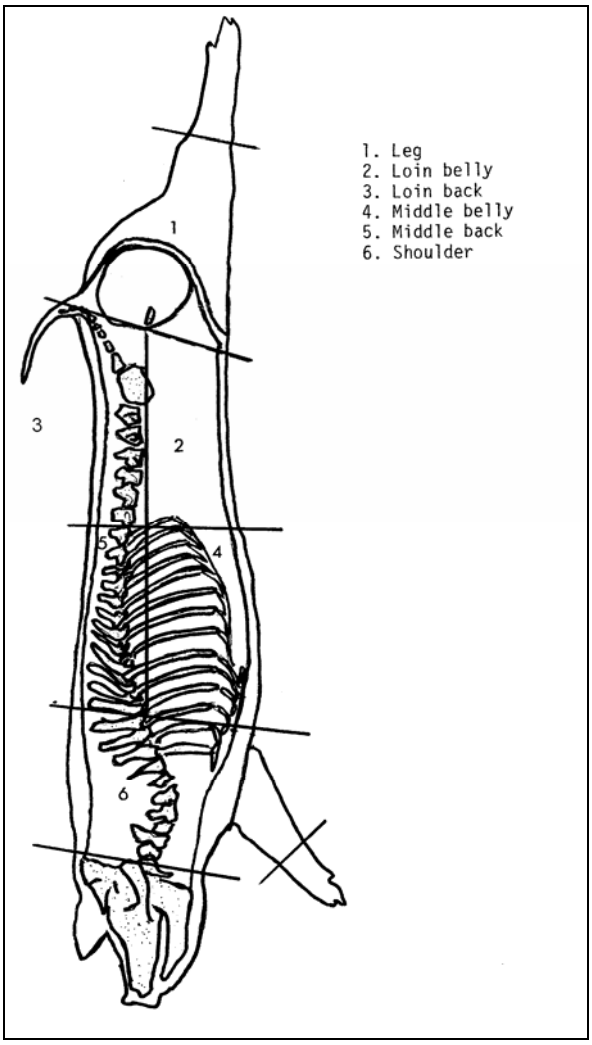
The carcasses were hung in a cold storage room (4°C) for 12 hours before they were dissected. After removing the head, tail, kidneys, peritoneal- and intestinal fat from each carcass (Fig 1) it was sawn into two halves from top to bottom. The right side was dissected to determine the yield of skin, bone, fat and lean meat.

The fillet was removed by cutting it away on the inside of the carcass directly below the hip bone by cutting along the hip bone and the lumbar vertebrae. Membranes and connective tissue were also removed from the fillet. The neck was removed by cutting at a 90° angle to the ventral line between the last cervical

and first thoracic vertebrae, the rind, bones and fat were then dissected. The shoulder was removed by cutting along the inside of the front leg and around the shoulder-blade up to the spinal cord and along the 5-6th thoracic vertebrae. The trotters were removed by cutting through the metacarpal region (joint between the carpal bones and the radius and ulna). The rind, fat and bones were dissected from the remaining part of the right shoulder.

The hind leg was removed between the 2nd and 3rd sacral vertebrae perpendicular to the stretched leg. The trotter was removed from the ham at the distal end of the tibia and fibula parallel to the cut made to remove the leg from the carcass. The trotters were removed by cutting through the crural region (across the middle of the tibia and fibula). The rind, fat and bones were dissected from the remaining part of the right leg. The belly was removed from the back by cutting parallel to the spinal cord, next to the eye muscle, approximately 18 cm from the spinal column i.e. a straight line from the posterior ventral point of the *M. psoas major* to the cranio-ventral edge of the 4th thoracic vertebra at the anterior end.

Figure 1 Carcass division for dissection (adapted from Siebrits 1984)



The back was split into the loin back and middle back by cutting through the back between the vertebrae at the caudal position of the last rib. The last three ribs were removed from the middle back by cutting through the spinal cord above the 3rd last rib (3 rib-cut). The belly was split into the middle belly and loin belly by cutting at the position of the last rib. The rind, bones and fat were dissected from each of the parts.

Data obtained in this study was analysed using the GenStat (2000) statistical program. A randomised trail design utilising 18 pens (animals) was used. Each sex group consisted of six pens, three control animals and three treated with pST. One of the animals died during the trail (cause of death was due to a heart-attack at the abattoir and no data was obtained from it). Differences between the groups were tested for by using analysis of variance (ANOVA). Using Fisher's F-test with a protected least significant difference (LSD) at a 5 % level of significance ($P<0.05$), treatment means were separated (Snedecor & Cochran, 1980). Percentage variance accounted for were calculated as the percentage ratio of the sum of squares of the parameter in relation to the total sum of squares, values below 10 % indicated a low residual and was therefore deemed coincidental.

A highly significant result was determined at $P<0.01$, whereas significant results were determined by outcomes where $P<0.05$.

Average daily gain was analysed by fitting a linear model to the weekly live weight measurements of the animals, the slope of the model would then represent the average daily gain.

3.4. Results and discussion

Feed intake, calculated cumulatively on a weekly basis, was not significantly influenced by pST or sex in this study (Table 2 and 3). Goodband *et al.* (1993) found a decrease in feed intake for animals treated with pST and fed diets with increased levels of lysine. Klindt *et al.* (1995) found a dose-dependant decrease in feed intake of boars and gilts slaughtered between 81.1 and 94.4 kg. Lysine levels was not adjusted in diets fed in their study. However, animals in the current study was subjected to pST treatment only at a live weight much higher than animals studied by these authors, which could have been the reason for the lack of response noted here.

Table 2 F Probabilities and percentage variance accounted for, for cumulative feed intake of animals fed up to 135 kg live weight.

	Sex		Treatment		Interaction	
Week	F Prob	% Var	F Prob	% Var	F Prob	% Var
Week 1	0.089	33.57	0.670	0.20	0.663	4.71
Week 2	0.269	21.09	0.902	0.11	0.968	0.47
Week 3	0.662	6.53	0.835	0.35	0.566	9.15
Week 4	0.134	26.11	0.979	0.00	0.298	14.62
Week 5	0.192	22.60	0.834	0.27	0.379	12.47
Week 6	0.239	20.32	0.847	0.24	0.435	11.17
Week 7	0.315	17.53	0.911	0.00	0.598	0.02
Week 8	0.362	15.57	0.876	0.18	0.599	7.49
Week 9[#]	0.379	15.08	0.812	0.42	0.653	6.29
Week 10[#]	0.503	10.71	0.589	2.26	0.651	6.54
Week 11[#]	0.679	7.28	0.721	1.23	0.587	10.17
Week 12[#]	0.893	1.81	0.919	0.09	0.516	11.13
Week 13[#]	0.805	3.44	0.602	2.24	0.589	8.66
Week 14[#]	0.643	6.74	0.347	7.08	0.691	5.61
Week 15	0.427	12.88	0.433	4.63	0.680	5.59

[#]pST treatment

Table 3 Average cumulative feed intakes (kg) of animals fed up to 135 kg live weight.

	Sex			Treatment	
Week	Gilt	Boar	Barrow	pST	Control
Week 1	14.97 ± 0.87	12.72 ± 0.94	16.12 ± 1.14	14.73 ± 0.81	14.19 ± 0.76
Week 2	27.57 ± 2.06	27.61 ± 2.22	32.94 ± 2.72	28.94 ± 1.93	28.76 ± 1.82
Week 3	44.30 ± 2.97	42.77 ± 3.20	47.34 ± 3.92	44.88 ± 2.77	44.12 ± 2.61
Week 4	62.58 ± 3.60	65.19 ± 3.88	75.87 ± 4.75	66.43 ± 3.36	66.81 ± 3.17
Week 5	82.28 ± 4.29	84.76 ± 4.63	96.33 ± 5.67	86.81 ± 4.01	86.15 ± 3.78
Week 6	102.60 ± 5.13	105.33 ± 5.53	118.10 ± 6.78	107.59 ± 4.80	106.87 ± 4.52
Week 7	124.31 ± 5.89	127.30 ± 6.35	140.05 ± 7.78	129.22 ± 5.50	128.94 ± 5.19
Week 8	144.12 ± 6.25	147.77 ± 6.73	159.85 ± 8.25	149.46 ± 5.84	148.80 ± 5.50
Week 9[#]	165.59 ± 6.63	170.95 ± 7.15	181.99 ± 8.76	172.06 ± 6.02	170.69 ± 5.84
Week 10[#]	190.09 ± 7.72	197.64 ± 8.33	205.80 ± 10.20	198.96 ± 7.22	194.22 ± 6.80
Week 11[#]	216.42 ± 8.13	222.87 ± 8.76	228.59 ± 10.73	223.26 ± 7.60	220.05 ± 7.16
Week 12[#]	242.37 ± 9.58	247.99 ± 10.33	249.22 ± 12.65	246.39 ± 8.96	245.58 ± 8.44
Week 13[#]	263.20 ± 10,10	272.30 ± 10.90	271.30 ± 13.30	271.66 ± 9.42	265.35 ± 8.88
Week 14[#]	281.40 ± 11.50	296.80 ± 12.40	293.40 ± 15.20	296.80 ± 10.80	283.30 ± 10.10
Week 15	298.20 ± 13.60	321.80 ± 14.70	322.60 ± 18.00	318.90 ± 12.70	306.40 ± 12.00

[#]pST treatment

It can be seen in Table 4 & 5 that pST also had no significant effect on the live weight increase of animals grown up to a 135 kg. Etherton *et al.* (1986) found a significant increase in carcass length and liveweight of pST treated pigs, slaughtered between 76 and 80 kg live weight, in contrast with what was observed in the current study, where animals was slaughtered at a higher weight. Chung *et al.* (1985) also found an increase in live weight, but found no significant influence on carcass length of pigs slaughtered at 60 kg live weight. Klindt *et al.* (1995) found a dose-dependant increase in gain of boars and gilts slaughtered between 81.1 and 94.4 kg. In this study no significant differences in live weight ($P>0.05$) and carcass weight were detected between pST- and control animals ($P>0.05$). Animals where slaughtered at an average live weight of 135 kg (ranging from 113 kg to 160 kg) and average carcass weight was 113.35 kg.

Table 4 F Probabilities and percentage variance accounted for, for live weights of animals fed up to 135 kg live weight.

	Sex		Treatment		Interaction	
Week	F Prob	% Var	F Prob	% Var	F Prob	% Var
Week 1	0.662	6.83	0.608	2.22	0.823	3.16
Week 2	0.383	15.50	0.579	2.43	0.958	0.64
Week 3	0.524	10.87	0.709	1.16	0.952	0.78
Week 4	0.449	13.29	0.669	1.49	0.980	0.30
Week 5	0.420	14.17	0.644	1.70	0.917	1.32
Week 6	0.393	15.28	0.653	1.58	0.873	2.03
Week 7	0.394	15.05	0.723	0.98	0.847	2.50
Week 8	0.372	15.57	0.674	1.34	0.762	4.00
Week 9[a]	0.375	15.42	0.727	0.92	0.731	4.64
Week 10[#]	0.291	18.75	0.735	0.82	0.657	5.92
Week 11[#]	0.401	14.04	0.624	1.80	0.648	6.38
Week 12[#]	0.314	18.17	0.861	0.23	0.751	4.15
Week 13[#]	0.244	21.30	0.953	0.02	0.650	5.92
Week 14[#]	0.240	21.44	0.849	0.25	0.645	6.00
Week 15	0.143	28.43	0.600	1.77	0.797	2.83

[#]pST treatment

Table 5 Average liveweights (kg) of animals fed up to 135 kg live weight.

	Sex			Treatment	
Week	Gilt	Boar	Barrow	pST	Control
Week 1	30.33 ± 1.77	29.84 ± 1.90	32.49 ± 2.33	31.28 ± 1.65	30.12 ± 1.56
Week 2	38.17 ± 2.19	37.04 ± 2.36	42.23 ± 2.89	39.55 ± 2.05	38.00 ± 1.93
Week 3	44.71 ± 2.55	44.84 ± 2.75	49.21 ± 3.37	46.41 ± 2.38	45.28 ± 2.25
Week 4	51.46 ± 2.72	51.80 ± 2.93	56.96 ± 3.59	53.60 ± 2.54	52.23 ± 2.39
Week 5	58.12 ± 2.96	60.18 ± 3.19	64.75 ± 3.91	61.22 ± 2.77	59.68 ± 2.61
Week 6	65.52 ± 3.01	68.58 ± 3.24	72.51 ± 3.97	69.03 ± 2.81	67.55 ± 2.65
Week 7	73.06 ± 3.25	76.61 ± 3.50	80.56 ± 4.29	76.70 ± 3.03	75.53 ± 2.86
Week 8	80.22 ± 3.25	84.86 ± 3.50	87.63 ± 4.29	84.35 ± 3.03	82.94 ± 2.86
Week 9[#]	86.37 ± 3.46	91.76 ± 3.73	93.96 ± 4.57	90.68 ± 3.23	89.50 ± 3.05
Week 10[#]	92.58 ± 3.47	99.56 ± 3.74	100.54 ± 4.58	97.48 ± 3.24	96.42 ± 3.06
Week 11[#]	100.15 ± 3.61	107.25 ± 3.90	105.49 ± 4.77	104.93 ± 3.38	103.01 ± 3.18
Week 12[#]	108.00 ± 3.78	116.70 ± 4.08	113.57 ± 4.99	112.59 ± 3.59	112.20 ± 3.33
Week 13[#]	115.41 ± 4.08	126.03 ± 4.39	120.28 ± 5.38	119.85 ± 3.81	120.70 ± 3.59
Week 14[#]	122.08 ± 4.55	133.99 ± 4.90	127.04 ± 6.00	126.54 ± 4.25	128.26 ± 4.00
Week 15	128.69 ± 4.37	142.48 ± 4.71	135.02 ± 5.77	133.07 ± 4.08	136.81 ± 3.85

[#]pST treatment

However, when the FCR of these animals were calculated, a significant ($p<0.05$) influence pertaining to sex type and pST was detected (Table 6 & 7). In contradiction to the results obtained by Etherton *et al.* (1986) & Chung *et al.* (1985), all animals treated with pST in this study had an increased FCR. It is interesting to note that from week ten onwards very low F-probabilitie, (week ten and thirteen was significant) were detected for the interactions between sex and pST treatment, since these probabilities described more than 10 % of the variation, these observations cannot be seen as merely co-incidental. It can thus be seen in Table 8 that boars had a tendency to have an increased FCR when treated with pST. For all treatments boars converted their feed to live weight better than barrows and gilts from week ten onwards, however pST had a negative effect on the FCR of boars although they had the best FCR of all sex trypes.

Table 6 F Probabilities and percentage variance accounted for, for calculated FCR of animals fed up to 135 kg live weight.

	Sex		Treatment		Interaction	
Week	F Prob	% Var	F Prob	% Var	F Prob	% Var
Week 1	0.198	24.930	0.639	1.537	0.945	0.749
Week 2	0.571	9.070	0.946	0.037	0.667	6.456
Week 3	0.150	25.415	0.990	0.000	0.350	12.969
Week 4	0.533	7.441	0.742	0.638	0.109	30.504
Week 5	0.371	11.720	0.950	0.022	0.112	28.961
Week 6	0.314	13.396	0.925	0.048	0.101	29.498
Week 7	0.208	18.799	0.859	0.171	0.143	24.136
Week 8	0.159	21.391	0.978	0.003	0.126	24.676
Week 9[#]	0.105	25.281	0.894	0.084	0.108	24.838
Week 10[#]	0.024	33.967	0.637	0.746	0.032	30.382
Week 11[#]	0.012	43.799	0.411	2.355	0.100	18.409
Week 12[#]	0.022	37.742	0.529	1.446	0.072	23.101
Week 13[#]	0.009	39.376	0.066	10.838	0.047	21.194
Week 14[#]	0.018	27.382	0.002	39.901	0.259	7.133
Week 15	0.018	31.026	0.014	22.530	0.074	17.503

[#]pST treatment

Table 7 Average calculated FCR by week for animals fed up to 135 kg live weight.

	Sex			Treatment	
Week	Gilt	Boar	Barrow	pST	Control
Week 1	1.999 ± 0.114	1.763 ± 0.123	1.658± 0.151	1.808 ± 0.107	1.859 ± 0.100
Week 2	1.954 ± 0.084	1.835 ± 0.091	1.972 ± 0.111	1.923 ± 0.079	1.910 ± 0.074
Week 3	2.095 ± 0.057	1.944 ± 0.061	1.938 ± 0.075	2.010 ± 0.053	2.000 ± 0.050
Week 4	2.259 ± 0.098	2.155 ± 0.105	2.367 ± 0.129	2.225 ± 0.091	2.267 ± 0.086
Week 5	2.338 ± 0.086	2.195 ± 0.093	2.415 ± 0.114	2.304 ± 0.081	2.308 ± 0.076
Week 6	2.397 ± 0.076	2.259 ± 0.081	2.466 ± 0.100	2.371 ± 0.071	2.359 ± 0.067
Week 7	2.492 ± 0.074	2.317 ± 0.079	2.537 ± 0.097	2.435 ± 0.069	2.447 ± 0.065
Week 8	2.573 ± 0.066	2.394 ± 0.071	2.599 ± 0.087	2.520 ± 0.061	2.512 ± 0.058
Week 9[#]	2.665 ± 0.066	2.455 ± 0.071	2.677 ± 0.087	2.604 ± 0.062	2.585 ± 0.058
Week 10[#]	2.724[a] ± 0.048	2.557[b] ± 0.052	2.821[a] ± 0.063	2.706 ± 0.045	2.672 ± 0.042
Week 11[#]	2.786[a] ± 0.046	2.568[b] ± 0.050	2.824[a] ± 0.061	2.749 ± 0.043	2.690 ± 0.041
Week 12[#]	2.850[a] ± 0.059	2.581[b] ± 0.064	2.843[a] ± 0.079	2.785 ± 0.056	2.725 ± 0.052
Week 13[#]	2.875[a] ± 0.048	2.621[b] ± 0.052	2.878[a] ± 0.064	2.858[c] ± 0.045	2.722[d] ± 0.043
Week 14[#]	2.863[a] ± 0.048	2.640[b] ± 0.052	2.863[a] ± 0.063	2.923 ± 0.045	2.661 ± 0.042
Week 15	2.868[a] ± 0.052	2.694[b] ± 0.056	3.005[a] ± 0.069	2.944[c] ± 0.049	2.745[d] ± 0.046

[#]pST treatment

[a,b,c,d,] Row means with common superscript do not differ significantly (P>0.05).

Table 8 Average calculated FCR by week for animals fed up to 135 kg live weight (sex X treatment interaction).

	Boar		Gilt		Barrow	
	pST	Control	pST	Control	pST	Control
Week 1	1.71 ± 0.71	1.81 ± 0.17	2.00 ± 0.17	2.00 ± 0.15	1.61 ± 0.21	1.70 ± 0.21
Week 2	1.84 ± 0.13	1.83 ± 0.13	2.01 ± 0.13	1.90 ± 0.11	1.90 ± 0.16	2.04 ± 0.16
Week 3	1.97 ± 0.09	1.92 ± 0.09	2.04 ± 0.09	2.15 ± 0.07	2.03 ± 0.11	1.86 ± 0.11
Week 4	2.33 ± 0.15	2.00 ± 0.15	2.17 ± 0.13	2.34 ± 0.13	2.16 ± 0.18	2.55 ± 0.18
Week 5	2.37 ± 0.13	2.04 ± 0.13	2.26 ± 0.13	2.41 ± 0.11	2.28 ± 0.16	2.54 ± 0.16
Week 6	2.43 ± 0.11	2.11 ± 0.11	2.32 ± 0.11	2.46 ± 0.1	2.37 ± 0.14	2.56 ± 0.14
Week 7	2.46 ± 0.11	2.19 ± 0.11	2.41 ± 0.11	2.57 ± 0.10	2.45 ± 0.14	2.62 ± 0.14
Week 8	2.53 ± 0.10	2.27 ± 0.10	2.50 ± 0.10	2.64 ± 0.09	2.54 ± 0.12	2.65 ± 0.12
Week 9[#]	2.61 ± 0.10	2.32 ± 0.10	2.60 ± 0.10	2.72 ± 0.09	2.61 ± 0.12	2.74 ± 0.12
Week 10[#]	2.71[a] ± 0.07	2.42[b] ± 0.07	2.67[a] ± 0.07	2.78[a] ± 0.06	2.77[a] ± 0.09	2.87[a] ± 0.09
Week 11[#]	2.70 ± 0.07	2.45 ± 0.07	2.77 ± 0.07	2.80 ± 0.06	2.79 ± 0.09	2.86 ± 0.09
Week 12[#]	2.75 ± 0.09	2.43 ± 0.09	2.78 ± 0.09	2.91 ± 0.08	2.84 ± 0.11	2.85 ± 0.11
Week 13[#]	2.82[a] ± 0.07	2.45[b] ± 0.07	2.86[a] ± 0.07	2.89[a] ± 0.06	2.92[a] ± 0.09	2.85[a] ± 0.09
Week 14[#]	2.85 ± 0.07	2.45 ± 0.07	2.97 ± 0.07	2.77 ± 0.06	2.94 ± 0.09	2.80 ± 0.09
Week 15	2.92[a] ± 0.08	2.49[b] ± 0.08	2.93[a] ± 0.08	2.82[a] ± 0.07	3.01[a] ± 0.10	3.00[a] ± 0.10

pST treatment

[a,b,] Row means with common superscript do not differ significantly (P>0.05).

Average daily gain was analysed by fitting a linear model $R^2 \geq 98.7$. Although sows (0.869 kg/day) and barrows (0.848 kg/day) had a slower rate of gain than boars (0.934 kg/day), pST had no significant effect on the rate of gain attained by any group of animals in this experiment.

Animals were slaughtered and dissected as described earlier, probabilities for differences are tabulated in Table 9.

Table 9 F probability and % variance accounted for in different carcass cuts of animals slaughtered at an average bodyweight of 135 kg.

	Sex		Treatment		Interaction	
Carcass quality parameter	F Prob	% Var	F Prob	% Var	F Prob	% Var
% Fillet	0.599	7.841	0.970	0.010	0.470	11.823
% Intestinal- & peritoneal fat	0.616	7.912	0.980	0.006	0.684	6.154
% Thigh	0.475	9.442	0.289	7.346	0.261	18.031
% Loin belly	0.777	4.124	0.767	0.737	0.644	7.310
% Middle Belly	0.727	4.327	0.350	6.289	0.316	16.889
% Loin Back	0.187	15.107	0.026	25.662	0.158	16.869
% Middle Back	0.454	6.219	0.103	11.587	0.020	41.922
% Shoulder	0.034	40.503	0.166	9.499	0.772	2.295
% Trotters	0.056	39.188	0.871	0.143	0.710	3.662
% 3rib	0.911	1.449	0.799	0.523	0.454	13.095
% Head	0.174	23.424	0.515	2.577	0.395	11.490

As can be seen from Table 9, pST had very little effect on the commercial cuts. Animals treated with pST had a significantly lower percentage (11.18%) loin back (p=0.026) than control animals (12.05%). The percentage middle back showed a treatment sex interaction where pST caused a significantly lighter middle back in the boars and barrows (see Table 10), but not in the gilts. No significant differences could be detected with pST treatment for any of the other carcass cuts.

Table 10 Effect of pST on the percentage middle back dissected from pigs slaughtered at average 135 kg.

Sex	pST	Control	P
Boar	9.86 [a]	10.96[b]	0.028
Gilt	10.55[a]	9.94[a]	0.160
Barrow	10.11[a]	11.30[b]	0.036

[a,b] Row means with common superscript do not differ significantly (P>0.05).

Although the treatment effect was not significant (P>0.05) for the entire middle back, a trend (P<0.1) was detected for percentage bone in the middle back, with the pST treated (14.17% *vs.* 13.18%) animals having more bone than that of the control animals. This is supported by the data analysed for the 3-rib cut: pST treated animals contained a significantly higher percentage bone (13.41% *vs.* 11.45%) than the control animals (p=0.042).

When the data was combined for all the cuts (Table 11) it was found that animals treated with pST had a higher percentage (p=0.024) skin (5.04%) than the control animals (4.28%). Although boars had a

significantly higher percentage ($p<0.05$) skin than barrows and gilts there was no sex X treatment interaction detected (Table 6).

Table 11 F probability and percentage variance accounted for for total percentage skin, bone, fat and lean meat of animals slaughtered at an average bodyweight of 135 kg

	Sex		Treatment		Interaction	
Carcass quality parameter	F Prob	% Var	F Prob	% Var	F Prob	% Var
%Skin	0.001	59.218	0.030	12.416	0.250	6.324
%Bones	0.917	1.426	0.365	7.242	0.885	2.014
%Fat	0.300	15.870	0.310	6.677	0.374	12.677
%Lean meat	0.790	3.595	0.343	7.325	0.634	7.083

Table 12 Average values obtained for carcass characteristics (Mean ± s.d.) as analysed in Table 11.

	Sex			Treatment	
Carcass parameter	Gilt	Boar	Barrow	pST	Control
%Skin	$4.36^{a} \pm 0.23$	$5.71^{b} \pm 0.25$	$3.04^{a} \pm 0.30$	$5.04^{a} \pm 0.20$	$4.28^{b} \pm 0.21$
%Bones	11.23 ± 0.34	11.03 ± 0.36	11.12 ± 0.45	11.32 ± 0.30	10.93 ± 0.32
%Fat	21.29 ± 1.76	18.03 ± 1.90	22.45 ± 2.32	$19.25 \pm 1.60.$	21.73 ± 01.60
%Lean meat	64.13 ± 1.62	64.02 ± 1.75	62.46 ± 2.14	64.63 ± 1.43	62.64 ± 1.51

[a,b] Row means with common superscript do not differ significantly ($P>0.05$).

These results did not support reports by numerous authors (Klindt, *et al.* 1992; Klindt *et al.* 1995) who studied lighter animals and found a reduction in body fat as well as an increase in lean muscle. It could be speculated that the lack of response detected in this study (especially on % fat) is probably attributable to the low number of replicates combined with the high slaughter weights, where the percentage fat reduction with pST could be so small that the variation between treatments was higher than the possible effect of the treatment.

Unfortunately the increase in average daily gain and decrease in FCR, as referred by other authors (Etherton *et al.,* 1986 and Chung *et al.,* 1985), was not seen in this study. However, it appears that pST treatment caused boars to have similar (though slightly higher) FCR's than gilts and barrows. As the animals slaughtered in this study were slaughtered at a higher body mass, this could have caused the animals to respond in a different manner than less mature animals used in the referenced studies.

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Chapter 4: The influence of porcine somatatropin (pST) on pork quality and carcass characteristics of pigs slaughtered at 127 kg live weight

4.1. Abstract

Forty-eight F1 crossbred (commercial type terminal crosses) pigs (boars, barrows and gilts) with an initial weight of 27.2 ± 2 kg were used to investigate the effect of porcine somatotropin (pST) (administered for 6 weeks prior to slaughter) on meat quality- and carcass characteristics (measurements) of pigs slaughtered at an average of 127 kg liveweight in the South African scenario. No significant pST effects were found for live weight, carcass weight, carcass length, ham length or chest depth. Likewise no significant pST effect was found for drip loss, water binding capacity, Hennessey colour and pH_1 measured on the *M. longissimus lumborum*. However control animals had a slightly higher pH_{24} value. Colour (CIELab) of the muscle was significantly affected by pST treatment, with lower L*, a* and b* values measured, indicating a slightly darker, less red colour for pST treated animals. A significant increase was also found in muscle area measured on a loin cut (*M. longissimus lumborum)* by video image analysis (VIA) as well as a significant decrease in extramuscular fat (back fat) area of boars and barrows treated with pST. No pST effect was found on the distribution of intra muscular fat for all animals. It can thus be concluded that pST reduced the backfat thickness and increased muscle area without influencing any of the meat quality parameters measured negatively.

Keywords: pork, pST, meat quality, colour, yield

4.2. Introduction

Increasing consumer demand for healthy, lean and low in cholesterol meat has prompted the development of numerous and exciting new technologies such as administering exogenous pST to growing animals to produce meat showing these qualities.

As seen by Johnston *et al*. (1993), the effect of pST administration to growing pigs decreased fat content and increased protein content (14.7 % *vs.* 16.4 %) of carcases. Growth performance was also improved (ADG of 0.92 *vs.* 0.88 for pigs from 59-105 kg). This increase in growth rate resulted in the animals being ready for slaughter at an earlier age.

Etherton *et al*. (1986) & Chung *et al*. (1985) found an increase in *Longissimus* muscle area with pST treatment, but no effect on backfat thickness for all animals slaughtered at the same bodyweight (under 100 kg). However, Carter & Cromwell (1998) found a significant decrease in backfat thickness as well as an increase in *Longissimus* muscle area of pigs treated with pST between 75 and 109 kg bodyweight.

The amount of fat and protein in meat products are not the only meat quality factors that are important to the consumer. A large portion of South African pork is sold fresh where visual appraisal plays a

major role in consumer decisions when it comes to pork products. Should any meat quality characteristic have a negative impact on visual appraisal, the customer would reject such a product in favour of a more appealing product. Meat colour and the amount of exudate seeping from meat do have such an impact on visual appraisal. Visual colour, pH_1, pH_{24} and drip loss of pST treated animals have been shown not to be affected by treatment (Goodband *et al*., 1990 & Ender *et al*., 1989). However decreased b* values (9.4 - 8.8) was found by Fabry *et al*. (1991), and a numerical, though non-significant, decrease in L* values (52.9 to 51.1) was observed when they investigated the use of pST.

No South African study has been documented to ascertain whether pST treatment had an effect on the meat quality- and carcass characteristics of pigs slaughtered at 127 kg live weight. Therefore this study was conducted to determine the effect of pST on pork quality characteristics in the South African scenario.

4.3. Materials and methods

Forty-eight F1 crossbred animals (commercial type terminal crosses) were housed in groups of eight (six pens) that were equally divided between the three sex types: boars, gilts and barrows and two treatments (control and pST). The experiment started with animals of 9-10 weeks of age, weighing 27.2 ± 2 kg. Each pen was equipped with a self-feeder and automatic water nipple. The facilities comprised of a commercial type grower house with temperature control *via* automatically opening curtains, average ambient temperatures measured in the houses ranged from 7-27 °C, with an average temperature of 16°C.

Animals were randomly allocated to either the pST treatment group or to the control group. Porcine somatotropin was administered to animals allocated to the pST treatment group after reaching an average bodyweight of 95 kg. A daily dose of 1 ml (5 mg rpST) reconstituted Reporcin® (Alpharma Animal Health, Victoria, Australia) was administered intramuscularly at the base of the neck for 6 weeks prior to slaughter.

A commercial grower diet (Diet 1, Table 1) containing 18 % crude protein (CP), 1.1 % lysine, 14 MJ/kg digestible energy and oxytetracycline (10%) (included at 2 kg/ton) was fed for the first 14 days after arrival. Thereafter Diet 2 was fed until 6 weeks into the trail, when animals attained an average live weight of c.a. 65 kg. Diet 2 had the same composition as Diet 1, but contained no medication.

Diet 3, containing 16 % crude protein, 0.9 % lysine and 13.5 MJ/kg digestible energy was then fed to all the animals from 6 to 12 weeks into the trail (average live weight *ca.* 95 kg).

It is well documented that voluntary feed intake of pST treated pigs decrease significantly (Kanis *et al*. 1990 & Johnston *et al*. 1993). To ensure that the control- and pST treated groups had similar total protein (lysine) intakes, a diet with a higher concentration protein was fed to the pST treated groups. Thus, when administration of pST commenced at 12 weeks the pST treated animals was fed an 18 % CP diet (Diet 2) until the end of the trail. Whilst the control animals remained on the 16% CP diet, Diet 3. All animals had *ad libitum* access to the feed.

Table 1 Ingredient and nutrient composition (g/kg) of diets fed to pigs

Ingredient	Diet 1	Diet 2	Diet 3
Yellow maize	689.7	688.2	674.4
Soya bean oilcake meal (47% CP)	116.1	127.3	118.6
Sunflower oilcake meal (38% CP)	33.8	32.0	113.0
Fishmeal (65% CP)	79.9	72.9	-
Wheaten bran	50.0	50.0	50.0
Synthetic lysine	9.0	9.0	3.2
Synthetic methionine	-	-	4.0
Synthetic threonine	-	-	8.0
Monocalcium phosphate	9.4	10.1	16.8
Feed lime	11.8	12.0	14.9
Fine salt	2.4	2.6	3.9
Vitamin and Mineral premix	4.0	4.0	4.0
Oxitetracycline (10%)	2.0	-	-
[1]Crude protein	180.0	180.0	160.0
[1]DE MJ/kg	14	14	13.5
[1]Lysine	11	9	9

[1]Calculated from analysed raw materials

Animals were slaughtered after 15 weeks in this investigation, at an average live weight of 127 kg in a commercial abattoir. Animals were transported and handled in a calm manner until slaughter. Due to the vehicle - design, groups of animals had to be mixed during transport and in the holding pens at the abattoir.

Animals were led into a stunning cage where they were stunned with an electrical stunner set at 220V and 1.8A, with a current flow of no longer than six seconds. Electrodes were placed at the base of the ear. Within 10 seconds exsanguination followed, and within 50 seconds shackling and hoisting of the carcass was completed. Scalding commenced within 5 minutes after stunning. Thereafter the carcasses were dressed using the standard commercial procedures and stored overnight at 4ºC.

Muscle pH was determined 45 to 60 minutes (pH_1) *post mortem* and again at 24 hrs *post mortem* (pH_{24}). The probe was inserted into the muscle (*longissimus lumborum)* from the inside of the carcass between the second and third lumbar vertebrae counting from the caudal end, about 45 mm from the midline. This was done to prevent the probe being covered by fat and possibly interfering with the measurements.

Backfat thickness and muscle depth were determined at slaughter with the Hennessey® grading probe (Hennessey Grading Systems Ltd., Auckland, New Zeeland) at the P2 position, 45mm from the dorsal midline, on the right side of the carcass, between ribs 13 and 14. Using these measurements, the percentage lean meat was calculated using the following formula:

$$LMP = 72.5114 – (0.4618 \times FT) + (0.0547 \times MD) \quad (1)$$

Where LMP = Lean meat percentage, FT = fat thickness (mm) and MD = meat depth (mm) (South African Government Gazette, 26 June 1992).

An intrascope was also used to measure backfat thickness at the same position.

The following carcass dimensions were measured (fig. 1): length of the carcass, from the cranial edge of the *Symphys pubis* to the cranial edge of the first rib at the angle of curvature, the length of the ham from the cranial edge of the *Symphys pubis* to the medio-distal point where the hind trotter was removed, ham circumference around the widest part of the ham and chest depth at the deepest point of the chest.

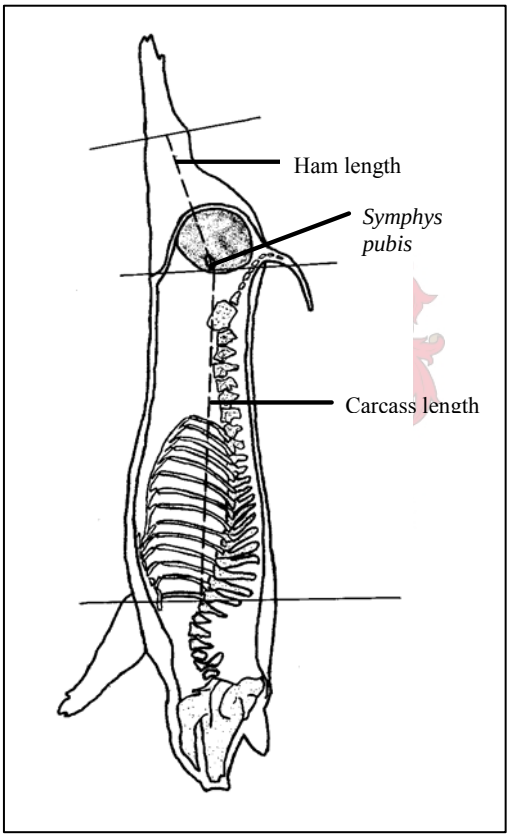

Figure 1 Different carcass measurements taken (adapted from Siebrits, 1984).

The last three thoracic vertebrae as well as all muscle and soft tissue (M. *longissimus et thoracis*) were subsequently removed by cutting through the fourth and third last ribs cranially and caudally between the first lumbar vertebra and last thoracic vertebra. This three rib cut was subsequently weighed and split in half. The left half (fig. 2) was marked and sealed in a plastic bag and frozen at -20°C. The remaining half was cut into 25 mm thick cuts (chops), of which the first few were discarded. A cut was then selected to determine drip loss. Other cuts were randomly selected for the following determinations: water holding

capacity and to use VIA (video image analysis) to determine intramuscular fat percentage, extramuscular fat percentage and percentage meat.

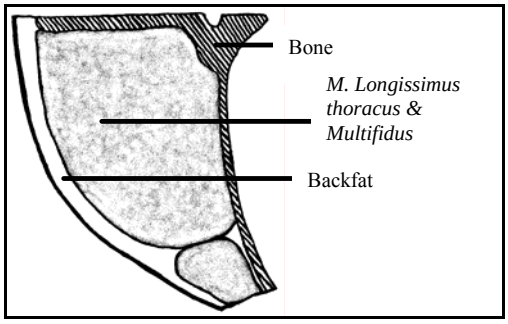

Figure 2 Representation of a typical loin-cut used for VIA.

Two systems where utilised to measure meat colour: The Hennessey® probe (Hennessey Grading Systems Ltd., Auckland, New Zeeland) and a Minolta® chromameter CR-200 (Minolta AG, Langenhagen, Germany). Colour was determined at slaughter with the Hennessey® grading probe at the P2 position, 45mm from the dorsal midline on the right side of the carcass, between ribs 13 and 14. The Hennessey probe measures reflectance from the meat surface (black-white range).

Meat colour was measured with a Minolta® chromameter on the cut end of the selected eye muscle after it was allowed to bloom for 30 minutes. This system uses the principle of adding and subtracting the primary hues: red, green and yellow to match any colour. L* represents brightness, a* represents the red-green range and b* represents the blue-yellow range (Swatland, 1984). Measurements where taken at three different positions on the muscle surface and an average was then calculated.

Loin-cut drip loss was determined by suspending a loin-cut for 24 hrs in a plastic bag at 5°C and determining the weight loss of the loin-cut over this period (Honikel, 1987).

Water binding capacity was calculated by using the method described by Hamm, as quoted by Swatland (1984) to determine water loss. A sample of 0.3g was pressed on a filter paper at a constant pressure of 35 kg cm $^{-2}$ between two plates for five minutes. The areas covered by the flattened meat sample and the stain from the meat sample was marked and measured using VIA. The meat-covered area was subtracted from the total stained area to obtain the wetted area, the water content was then calculated as:

$$\text{mg } H_2O = \frac{\text{wetted area (cm}^2\text{)}}{0.0948} - 8.0$$

Data obtained in this study was analysed using the GenStat (2000) statistical program. A randomised trail design utilising six pens was used. Each sex group consisted of two pens, one control group and one treated with pST (each group consisted of eight animals). Differences between the groups were tested for by

using analysis of variance (ANOVA). Using Fisher's F-test with a protected least significant difference (LSD) at a 5 % level of significance ($P<0.05$), treatment means were separated (Snedecor & Cochran, 1980). Percentage variance accounted for was calculated as the percentage ratio of the sum of squares of the parameter in relation to the total sum of squares, values below 10 % indicated a low residual and was therefore deemed coincidental.

A highly significant result was determined at $P<0.01$, whereas significant results were determined by outcomes where $P<0.05$. Differences were considered to be tendencies when $P<0.1$ provided it described more than 10 % of the variation.

4.4. Results and discussion

In the current study pST had no significant ($P>0.05$) effect on any of the physical carcass weights and dimensions tabulated in Tables 2 & 3, although sex type had an effect on most of the parameters, no sex type x treatment effect was observed.

Table 2 The effect of pST on different carcass characteristics of pigs slaughtered at 127 kg live weight.

	Sex		Treatment		Interaction	
Carcass quality parameter	F Prob	% Var	F Prob	% Var	F Prob	% Var
Live weight	0.003	22.20	0.162	3.35	0.094	8.30
Carcass weight	0.006	20.64	0.272	2.19	0.173	6.48
Carcass length	0.023	16.19	0.672	0.35	0.251	5.58
Ham length	0.005	22.25	0.211	2.95	0.622	1.76
Ham circumference	0.003	22.06	0.140	3.82	0.139	6.97
Chest depth	0.078	11.20	0.424	1.34	0.292	5.23

Table 3 Average values for the different carcass quality parameters analysed statistically in Table 2 (Mean ± s.d.).

	Sex			Treatment	
Carcass quality parameter	Gilt	Boar	Barrow	pST	Control
Live weight	123.63[a] ± 2.27	133.48[b] ± 2.90	121.93[a] ±2.27	129.46 ± 1.83	125.54 ± 1.83
Carcass weight	100.21[ab] ± 1.83	104.39[a] ± 1.77	95.60[b] ± 1.83	101.43 ± 1.48	98.9 ± 1.48
Carcass length	89.18[a] ± 0.72	91.00[b] ± 0.69	88.15[a] ± 0.72	89.67 ± 0.58	89.28 ± 0.58
Ham length	54.69[a] ± 0.48	56.56[b] ± 0.46	54.46[a] ± 0.48	55.62 ± 0.39	54.91 ± 0.39
Ham circ.	78.15[a] ± 0.51	79.25[b] ± 0.49	76.71[a] ± 0.51	78.53 ± 0.41	77.60 ± 0.41
Chest depth	21.11 ± 0.33	20.56 ± 0.32	20.00 ± 0.33	20.73 ± 0.27	20.38 ± 0.27

[a,b] Row means with common superscript do not differ significantly (P>0.05).

All weights are in kg and lengths in cm.

Although a nominal increase in carcass weight of pST treated animals was seen, the difference did not reach statistical significance (P=0.167). Etherton *et al.* (1986) found a significant increase in carcass length and live weight of pST treated pigs, slaughtered between 76 and 80 kg live weight, in contrast with what was observed on heavier pigs (127 kg live weight) in the current study. Chung *et al.* (1985) also found pST to increase live weight, but found no significant influence on carcass length of pigs slaughtered at 60 kg live weight. The lack of statistical response of these parameters to pST treatment could be attributed to the pigs in this investigation being slaughtered at a higher bodyweight. The expected sex effects was seen where boars were heavier than gilts and barrows.

When muscle depth was measured with the Hennesy probe, no significant (P>0.05) effect were observed for pST. However, a significant pST (P< 0.05) effect (about 3 mm reduction) was seen for backfat depth measured by the Hennessey probe as well as with the intrascope.

When calculating muscle percentage from the measured backfat depth and muscle depth (see equation 1), the Hennesey probe uses two constants. The effect of backfat depth is ten times higher than for muscle depth hence the greater influence of backfat depth in the prediction of percentage meat calculated by the Henessy probe, as can be seen in the values in Table 4.

Table 4 Average values for different carcass characteristics, as measured with a Hennessey probe and an intrascope.

	Sex			Treatment	
Carcass quality parameter	Gilt	Boar	Barrow	pST	Control
Hennessey muscle depth	64.41± 1.98	61.76 ± 1.92	61.78 ± 1.98	63.08 ± 1.60	62.18 ± 1.60
Hennessey fat depth	15.58 ± 0.92	16.10 ± 0.89	18.58 ± 0.96	15.17[a] ± 0.74	18.31[b] ± 0.74
Calculated % lean meat	68.85 ± 0.47	68.46 ± 0.46	67.32 ± 0.47	68.95[a] ± 0.38	67.47[b] ± 0.38
Intrascope fat depth	14.95± 0.80	15.81± 0.77	17.00 ± 0.80	14.44[a] ± 0.64	17.40[b] ± 0.64

[a,b] Row means with common superscript do not differ significantly (P>0.05).

All measurements are in mm.

No pST x sex type interaction (P>0.05) was observed for any of these observations (Table 5). However, barrows had a tendancy (P<0.1) to have a deeper fat layer than boars and gilts. This was further supported by results obtained by VIA where boars and gilts had a significantly larger (P<0.05) muscle surface area of the loin cut than barrows (Table 6) and less extramuscular fat (P<0.05). Porcine somatotropin significantly (P<0.05) increased the muscle area of the loin-cut for all sexes.

Table 5 The effect of pST on meat and fat distribution of the loin cut, as measured by VIA, of pigs slaughtered at 127 kg live weight. (F – prob values and % variance accounted for.)

	Sex		Treatment		Interaction	
Carcass quality parameter	F Prob	% Var	F Prob	% Var	F Prob	% Var
Muscle area	0.049	12.16	0.017	11.69	0.676	1.48
Extramuscular fat area	0.015	13.87	0.002	16.23	0.042	10.28
Intramuscular fat area	0.531	3.045	0.363	2.01	0.949	0.25
Extramuscular fat as % of muscle	0.006	17.19	0.001	17.65	0.121	6.52
Intramuscular fat as % of muscle	0.461	3.77	0.679	0.42	0.920	0.40

Table 6 Mean values (± s. d.) obtained for meat and fat areas and ratios between them of the loin cut, as measured by VIA, of pigs slaughtered at 127 kg live weight.

	Sex			Treatment	
Carcass quality parameter	Gilt	Boar	Barrow	pST	Control
Muscle area	$6001^{a} \pm 182$	$5779^{ab} \pm 176$	$5362^{b} \pm 182$	$5989^{a} \pm 147$	$5442^{b} \pm 147$
Extramuscular fat area	$1357^{a} \pm 115$	$1399^{a} \pm 111$	$1796^{b} \pm 115$	$1289^{a} \pm 93$	$1740^{b} \pm 93$
Intramuscular fat area	6.72 ± 1.55	9.04 ± 1.50	7.30 ± 1.55	8.52 ± 1.25	6.91 ± 1.25
Extramuscular fat as % of muscle	$23.02^{a} \pm 2.58$	$25.43^{a} \pm 2.49$	$34.66^{b} \pm 2.58$	$22.30^{a} \pm 2.0$	$33.00^{b} \pm 2.08$
Intramuscular fat as % of muscle	0.112 ± 0.028	0.1615 ± 0.027	0.138 ± 0.028	0.144 ± 0.023	0.132 ± 0.023

[a,b] Row means with common superscript do not differ significantly (P>0.05).

All measurement are in mm^2, ratios are expressed as %.

The significant interaction (P=0.042) for extramuscular fat between treatment and sex is indicated in Tables 6 & 7. The area covered by subcutaneous fat of boars and barrows were significantly (P<0.05) reduced by pST treatment, with no effect detected for gilts (P>0.05). Porcine somatotropin was seen to have a reducing effect between all sexes when extramuscular fat area was expressed as a percentage of the area covered by muscle (P>0.05). This means that pST treatment increased the muscle percentage and decreased the extramuscular fat percentage in a manner that the differences between the sexes was reduced. Thus, more uniform fat-muscle distribution between carcasses was obtained by pST treatment. This is similar to the results obtained by Campbell *et al*. (1989).

Table 7 Tabulation of the interaction between pST treatment and sex for extramuscular fat.

	Interaction					
	Boar		Gilt		Barrow	
	pST	Control	pST	Control	pST	Control
Extramuscular fat area	$972^{a} \pm 157$	$1826^{b} \pm 157$	$1350^{a} \pm 168$	$1364^{a} \pm 157$	$1566^{b} \pm 157$	$2026^{b} \pm 168$

[a,b] Row means with common superscript do not differ significantly (P>0.05).

In the current study, no differences were found (P>0.05) between sexes for either area covered by – or percentage intramuscular fat. However, higher intramuscular fat levels were expected in the barrows and gilts relative to the boars as described by Lawrie (1991). Similarly, no pST effect was found (P>0.05) for either the area covered by intramuscular fat or this area expressed as a percentage of the total area covered by the muscle and fat. These results differ from that reported in the literature where Beerman *et al.* (1990) and Hagen *et al.* (1991) found a significant decrease in intramuscular fat of pigs treated with pST and slaughtered above 100 kg live weight. This contradiction in results could be due to the fact that different pig strains respond differently to pST treatment (D'Sousa & Mullan, 2001). An alternative explanation might be the fact that the animals in the current study were slaughtered at a higher liveweight and this might have influenced the effect.

The calculated probabilities of all the meat quality characteristics observed in this study are tabulated with the percentage variation accounted for by each variable in Table 8. A tendency (P>0.05, % variance accounted for > 10%) for waterbinding capacity to show a sex type x treatment interaction was observed. However, since waterbinding capacity has a high correlation with drip loss and no interaction was observed for drip loss, the tendency was deemed coincidental. For all other parmeters no significant interactions were observed between sex type and treatment, therefore only the main effects of sex and treatment will be discussed further.

Table 8 F probability and % variance accounted for in different meat quality characteristics of pork obtained from animals slaughtered at 127 kg live after treatment with pST.

	Sex		Treatment		Interaction	
Carcass quality parameter	F Prob	% Var	F Prob	% Var	F Prob	% Var
pH_1	0.515	1.001	0.517	1.001	0.626	2.216
pH_{24}	0.097	9.564	0.049	5.056	0.282	5.056
Drip loss	0.992	0.038	0.060	8.427	0.733	1.414
Water binding capacity	0.949	7.507	0.610	0.212	0.068	11.590
CIE L*	0.508	2.792	0.016	12.714	0.445	3.354
CIE a*	0.810	0.810	0.002	20.551	0.593	2.029
CIE b*	0.779	1.070	0.017	13.287	0.934	0.293
Hennessey Colour	0.494	3.127	0.128	5.279	0.374	4.389

Table 9 contains the mean values and the combined standard error of the mean for the pH observations. In the current study no effect was found for pST or sex or interaction between the two parameters on pH_1 ($P>0.5$). However, pH_1 was below 5.9 for all treatments (treatment and control). This decrease in initial pH, as reported by Fisher & Mellett (1997) is a common phenomenon frequently associated with the formation of PSE (pale soft exudative) meat.

No signifficant differences between sexes was observed ($P>0.05$) for pH_{24} (Table 9). However, the control animals had a significantly higher pH_{24} than pST treated animals ($P=0.049$). Goodband *et al.* (1993) & Beerman *et al*. (1990) obtained a slightly higher, but similar pH_{24} values for pST treated pigs, but also postulated that pST had no negative impact on meat quality in terms of DFD (dry, firm and dark) and PSE meat formation. In an earlier investigation, Goodband *et al.* (1990) found that the pH_{24} of the *longissimus* muscle was not as dramatically affected by pST treatment as that of the *M. semimembranosus*. However, the levels found in the *M. semimembranosus* were not low enough to affect pork quality. In later studies Goodband *et al.* (1993) also found a significant, but very slight reduction of pH_{24} in the *M. longissimus thoracis* of barrows treated with pST and concluded that it was unlikely that pST treatment would have had any significant effect on the formation of DFD- or PSE pork.

Table 9 Average values obtained for meat quality characteristics analysed in Table 8. (Mean ± s.d.)

	Sex			Treatment	
Carcass quality parameter	Gilt	Boar	Barrow	pST	Control
pH_1	5.74 ± 0.10	5.91 ± 0.106	5.83 ± 0.106	5.87 ± 0.09	5.79 ± 0.09
pH_{24}	5.47 ± 0.03	5.37 ± 0.03	5.38 ± 0.035	5.37^a ± 0.28	5.44^b ± 0.028
Drip loss	0.40 ± 0.013	0.40 ± 0.013	0.40 ± 0.013	0.42 ± 0.010	0.387 ± 0.016
Water binding capacity	4.23 ± 0.367	4.16 ± 0.355	4.19 ± 0.367	4.60 ± 0.296	3.79 ± 0.296
CIE L*	53.798 ± 0.890	52.566 ± 0.860	53.878 ± 0.890	52.123^a ± 0.718	54.667^b ± 0.718
CIE a*	5.080 ± 0.370	5.292 ± 0.358	5.399 ± 0.370	4.559^a ± 0.299	5.956^b ± 0.299
CIE b*	6.006 ± 0.386	5.962 ± 0.373	6.320 ± 0.386	5.538^a ± 0.311	6.648^b ± 0.311
Hennessey Colour	64.410 ± 1.980	61.760 ± 1.920	61.780 ± 1.980	63.080 ± 1.600	62.180 ± 1.601

[a,b] Row means with common superscript do not differ significantly (P>0.05).

A direct cause of drip loss (Honikel *et al.*, 1986 & Honikel 1987) is protein denaturation and membrane leakage, which is caused by either a rapid reduction in pH, a low ultimate pH, or a combination of the two. In the current study, pH_1 was below 5.9 and pH_{24} was below 5.4. It is known that the isoelectric point of muscle protein is near pH 5.5 (Swatland, 1984). In the current study (Table 9), nearly all values were close to 5.5, explaining the high average drip loss (average 4.2 %) for all treatments. Thiel *et al*. (1993) found a small increase in drip loss in pigs receiving more than 150 µg pST/kg BW per day slaughtered at 90 kg bodyweight. In the current study there was a tendency (P=0.06) for pST to increase the muscle drip loss but only 8% of the variation between treatments is described by this effect (Table 8). McPhee *et al.* (1991) & Knight *et al*. (1991) found a slightly increased drip loss in animals treated with pST. No pST effect was found for waterbinding capacity (P=0.61) in the current study, as measured by the press method (Table 9).

Table 9 also shows the effect of the administration of pST on the CIELab and colour (determined by the Hennessey probe) values of the *M. longissimus lumborum* from pigs slaughtered at 127 kg live weight.

Colour measured with the Hennessey probe did not show any significant pST effect (P> 0.05) nor any sex type effect. Ender *et al*. (1989), Beerman *et al*. (1990) & Johnston *et al.* (1993) also measured the effect of pST on visual colour perception of a loin cut and found no effect of pST on a scale from extremely pale to dark.

There is very little reported evidence on the effect of pST on the CIELab colour values. Prusa *et al*. (1990) conducted CIELab measurements on processed meats from pST treated animals and found no differences in the processed products. In this study, the effect of pST on L* and b* was significant (P<0.05), whereas the effect on a* was highly significant (P<0.01). Lower values were found for animals receiving pST for L* (P=0.016), a* (P=0.002) and b* (P=0.016). The effect on b* (yellow-blue range) in the *M longissimus thoracis* of pST treated animals showed slightly (but significantly) less yellow and more green compared to control animals (P=0.016). This combined with the lower L* values (brightness) indicates that pST treated animals had a significantly darker colour meat compared to the control animals. The observed decrease in a* values in pST treated animals indicates a loss of red hue at the cut surface of the *Longissimus thoracis*. Beerman *et al*. (1990), on the other hand, found an increase in redness with pST treatment as well as a slightly darker muscle.

The concentration or dilution of muscle pigment by water content has been postulated as the cause of increased or decreased a* values in normal pigs (Ahmed *et al*. 1990). Higher muscle water content can also impact on meat colour either by causing the dilution of muscle pigment or, in itself, reflecting/scattering the light from the loin cut surface (Swatland, 1984).

Solomon *et al.* (1990) showed that pST treatment affects the distribution of muscle fibre types as well as the area covered by these muscle fibres. Beerman *et al*. (1990) found the effect to be only on the increase in muscle fibre (type I and II) area. Different levels of myoglobin occur in different muscle fibre types, which might influence the muscle colour, since myoglobin strongly absorbs green light, but reflects yellow and red light (Swatland, 1993). Further studies on pST treatment and CIELab values should take into account the distribution of muscle fibre types.

Hennessey probe measurements were taken at the same time as pH_1 (where no effect was observed), and it is known that pH, under certain conditions, influences meat colour (Swatland, 1993). There was lack of influence of pST on reflectance measured by the Hennessey probe whereas a significant effect was observed for CIELab values. This could be due to the time difference between the measurements, CIELab values were taken when pH_u (ultimate pH) was already attained, but the Hennessey measueremnt was taken on the slaughter line. The Hennessey probe was therefore not a good predictor of ultimate loin-cut colour differences caused by pST treatment found in this study.

4.5. Conclusion

In the current study, no significant pST effects were found for live weight, carcass weight, carcass length, ham length or chest depth. However, a significant increase was found in muscle area as well as a

significant decrease in extra muscular fat (back fat) area of boars and barrows. In this study no pST effect was found on the distribution of intra muscular fat.

Although great care had been taken by the research team to reduce stress conditions in the transport and slaughter of the animals, it is possible that PSE had developed, which was attributed to ante-mortem effects, rather than the effect of pST. In this study PSE might have had an overshadowing effect over any effect that pST administration might have had on any of these meat quality aspects. It is also clear that in this study, pST had no effect on the precipitation or prevention of PSE effects.

The evidence obtained in this study confirms results obtained by other researchers that pST has no significant ($P>0.05$) effect on most meat quality characteristics measured, including pH and water binding capacity. However a significant difference was seen in the effect of pST on CIELab values of the loin-cut, with the most prominent effects on a* values. Further studies looking at distribution of muscle fibre type might clear up the exact cause of these observed differences.

The production of leaner meat from heavier animals is a promising prospect and should have economic implications to the pork producer. However, South African pork producers are not paid on lean meat and percentage backfat only but also on carcass weight, the pigs in this study for instance would be classified as a "sausage pig", where the percentage meat calculation has no relevance to the price paid to the producer. Therefore for pST to be used successfully on heavier pigs in South Africa it will take a change in legislation as pertaining to carcass classification to accommodate the heavier carcasses as shown in this study.

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Chapter 5: General conclusion

Animals in the group housing system weighed average 127 kg and in the individual housing system weighed 135 kg when slaughered.

For group housed animals pST had no significant effect on the following parameters: Feed intake calculated cumulatively on a weekly basis, ADG, live weight, carcass weight, carcass length, ham length or chest depth, intramuscular fat area, muscle depth and colour measured with a Hennessey probe and waterbinding capacity. However, when the FCR of pigs in this investigation were calculated, there was a significant ($p<0.05$) influence by sex and pST detected. Boars converted their feed to live weight better than barrows and gilts from week ten onwards. Boars had a tendency to have an increased FCR when treated with pST. A significant increase was found in muscle area as well as a significant decrease in extra muscular (back fat) area of boars and barrows. A significant pST ($p<0.05$) effect (about 3 mm reduction) was seen for backfat depth measured by the Hennessey probe as well as with the intrascope. Porcine somatotropin significantly ($p<0.05$) increased the muscle area of the loin-cut for all sexes. The area covered by subcutaneous fat of boars and barrows were significantly ($p<0.05$) reduced by pST treatment, with no effect detected for gilts ($p>0.05$). Porcine somatotropin treatment increased the muscle percentage and decreased the extramuscular fat percentage so that the differences between sexes was reduced. Thus, more uniform fat-muscle distribution between carcasses was obtained by pST treatment. pH_1 was below 5.9 for all treatments (treatment and control). This decrease in initial pH is a common phenomenon frequently associated with the formation of PSE (pale soft exudative) meat. Control animals had a significantly higher pH_{24} than pST treated animals ($p=0.049$). The effect of pST on L* and b* was significant ($p<0.05$), whereas the effect on a* was highly significant ($p<0.01$). Lower values were found for animals receiving pST for L* ($p=0.016$), a* ($p=0.002$) and b* ($p=0.016$). The effect of pST on b* (yellow-blue range) in the *M longissimus thoracis* was lower yellow and higher green (but significantly) values ($p=0.016$). This combined with the lower L* values (brightness) indicates that pST treated animals had a significantly darker colour meat compared to the control animals. The observed decrease in a* values in pST treated animals indicates a loss of red hue at the cut surface of the *Longissimus thoracis*. Although great care have been taken by the research team to reduce stress conditions in the transport and slaughter of the animals, it is possible that PSE meat had developed, which was attributed to ante-mortem effects, rather than the effect of pST. In this study PSE might have had an overshadowing effect over any effect that pST administration might have had on any of these meat quality aspects. It is also clear that in this study, pST had no effect on the precipitation or prevention of PSE effects.

For individually housed animals no significant differences were found for the following characteristics: live weight, carcass weight, head, trotters, shoulder, middle back, middle belly, loin belly, thigh, fillet, carcass fat and kidney. Whereas pST caused a significantly lower percentage of the middle back of boars and barrows, but not in gilts, pST could only precipitate a lower percentage (11.18%) loin back of treated animals ($p=0.026$) *v.s.* control animals (12.05%). Although the effect was not significant ($p>0.05$) for

the entire middle back, a trend ($p>0.1$) was detected for percentage bone in the middle back, with the pST treated (14.17% *vs.* 13.18%) animals having more bone than that of control animals. This is supported by the data analysed for the 3-rib cut: pST treated animals contained a significantly higher percentage bone (13.41% *vs*. 11.45%) than the control animals ($p=0.042$). When the data was combined for all the cuts it was found that animals treated with pST had a higher percentage ($p=0.024$) skin (5.04%) than the control animals (4.28%).

In general, there was a lack of response to pST observed in these studies when compared to the literature. The only difference between this study and other studies is the ultimate slaughterweight, where animals in this study was slaughtered at 127-135 kg liveweight. The feeding recommendations (especially lysine levels), as well as the dose recommended by the manufacturer is based on animals treated between 60 and 90 kg bodyweight. It is possible that the pST dose was too low for the bodyweight of these animals (a response was seen in meat quality characteristics of lighter pigs in other studies), or that animals at this weight might require a different protein level for optimum conversion of feed to meat.

This study shows that there is no negative effect of pST on meat quality characteristics and carcass composition, in fact there is less variation between carcasses obtained from different sexes treated with pST. The producer can bring heavier animals to the market with a reduced backfat percentage and a greater percentage meat with the help of pST. The production of leaner meat from heavier animals is a promising prospect and can have economic implications for the pork producer. Unfortunately, South African pork producers are not paid on lean meat and percentage backfat only, the pigs in this study for instance would be classified as "sausage pigs", where the percentage meat calculation has no relevance to the price paid per kg carcass to the producer. The use of pST in the production of heavier carcasses can only be viable if a premium is paid for better carcass characteristics at this bodyweight and will require a change in legislation

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