Growth, carcase and meat characteristics of stress susceptible and stress resistant South African Landrace gilts

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Growth rate, average daily gain, feed conversion ratio, muscle pH, backfat thickness, dressing percentage, drip loss, cooking loss, water holding capacity, and shear force were measured in 47 South African Landrace gilts of which 30 were classified as stress resistant and 17 as stress susceptible with the halothane test. Stress susceptible pigs had a significantly higher ($P < 0,01$) dressing percentage, and significantly ($P < 0,01$) lower backfat thickness and muscle pH (*M. longissimus lumborum*). *M. longissimus thoracis* samples from the stress susceptible pigs cooked at 70°C for 60 minutes had a lower average shear force value ($P < 0,01$) than those from the stress resistant pigs. No other significant differences were found between the two groups of pigs. Stress susceptible pigs have the desirable attributes of leaner carcases with more tender meat, but have a low post mortem muscle pH_1, indicative of pale, soft, exudative pork which will neutralize to a great extent the desirable qualities these pigs might have.

Groeitempo, gemiddelde daaglikse toename, voeromsetverhouding, spier-pH, rugspekdikte, uitslagpersentasie, drupverlies, gaarmaakverlies, waterhouvermoë en snyweerstand van 47 Suid-Afrikaanse Landrassoggies is bepaal, waarvan 30 soggies as spanningsweerstandbiedend en 17 soggies as spanningsgevoelig geklassifiseer is volgens die halotaantoets. Spanningsgevoelige varke het 'n betekenisvol hoër ($P < 0,01$) uitslagpersentasie getoon en 'n betekenisvol ($P < 0,01$) dunner rugspekdikte en laer spier-pH-waarde (*M. longissimus lumborum*). Monsters van die *M. longissimus thoracis* van die spanningsgevoelige varke was gemiddeld ook sagter volgens snyweerstandwaardes ($P < 0,01$) as dié van spanningsweerstandbiedende varke indien gaargemaak vir 60 minute by 70°C. Geen ander betekenisvolle verskille tussen die twee groepe varke is gevind nie. Spanningsgevoelige varke het gesogte eienskappe soos maerder karkasse en sagter vleis, maar ook 'n lae post mortem spier-pH_1-waarde wat 'n aanduider is van bleek, pap en waterige vleis, en dié eienskap neutraliseer tot 'n groot mate die gesogte eienskappe waaroor sulke varke mag beskik.

Keywords: Stress susceptible pigs, growth characteristics, carcase characteristics, meat characteristics

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Introduction

It has been suggested that stress susceptibility in pigs is the result of selection for, and is associated with, heavily muscled pigs that have a high growth rate, improved feed efficiency, and lean carcases (Nelson, 1973). McGloughlin, Ahern, Butler & McLoughlin (1980) on the other hand have indicated that stress susceptibility is associated with reduced daily gain, a result confirmed by Mitchell & Heffron (1981) in a preliminary study, and which suggests that stress susceptible animals may be less economic to produce than stress resistant animals. We report here the results of an extended study of growth, carcase and meat characteristics of stress susceptible and stress resistant animals, with the aim of shedding more light on the matter.

Materials and Methods

Animals

Forty-seven South African Landrace gilts were used in the study. The animals were selected on the basis of a halothane screening test used at the Pig Performance Testing Station of the Animal and Dairy Science Research Institute at Irene (4% halothane — Fluothane, ICI — in oxygen at a flow rate of 2,5 l/min for 3 min (Rossouw, 1985; personal communication) at between 7 and 9 weeks of age. Thirty stress resistant pigs (no malignant hyperthermic reaction to halothane) and 17 stress susceptible pigs (malignant hyperthermic reaction to halothane) were selected. All the animals were housed at the Animal and Dairy Science Research Institute at Irene, from the age of 9 weeks in separate pens under normal husbandry conditions.

Growth studies

The pigs were allowed 3 weeks to adapt to their environment before growth tests were started. From an average age of 12 weeks until the end of the trial at the age of 21 weeks the pigs were weighed weekly. Feed was available *ad libitum* and the amount of feed consumed recorded.

Carcase and meat characteristics

At the end of the growth trial all the animals were again exposed to halothane. In this case the pigs were challenged with a 10% halothane concentration in oxygen at a flow rate of about 2,5 l/min for 30 seconds, followed by a 3 – 7% concentration for a total period of 10 min, and the results of this final test was used to classify the pigs as stress resistant or stress susceptible for the analysis of the results. The 10% halothane concentration was used to anaesthetize the pigs as quickly as possible to prevent excessive struggling, and the 3 – 7% halothane concentration to maintain anaesthesia. Animals which died as a result of halothane exposure were considered stress susceptible (Mitchell & Heffron, 1981). These animals were immediately dressed using normal slaughter and dressing procedures, and the carcases and meat used for the determination of carcase and meat characteristics. Survivors of halothane exposure (regarded as being normal or halothane negative) were allowed 2 weeks to recuperate, after which they were transported by road to the abattoir (2 km), and immediately electrically stunned, slaughtered and dressed. In both groups of animals a muscle sample was taken from the *M. longissimus lumborum* immediately after death or slaughter for determination of pH. Muscle samples were incubated in a moist nitrogen atmosphere at 37°C and pH determined at 15, 30, 45 and 60 min, and 24 h post mortem. At each of these times 2 g of muscle was homogenized in 10 ml of 5 mM iodoacetate (pH 7,0) (McLoughlin & Tarrant, 1968) and the pH was measured using a Labion 17 pH meter (Labotec).

The carcases were weighed after slaughter and chilled overnight in a chiller at 0°C after which they were again weighed. Twenty-four hours after death or slaughter the carcases were split. Carcase length was measured (length 1: between first cervical vertebrae and the *symphysis pubis*; length 2: between first thoracic vertebrae and the *symphysis pubis*), and backfat thickness was measured 60 mm from the midline between the 10th and 11th thoracic vertebrae. The outline of the *M. longissimus thoracis* was traced on graph paper, and the area determined. The *M. longissimus thoracis* of the right side was dissected between the 10th and the last thoracic vertebrae and vacuum packaged after the mass was recorded. The vacuum packaged sample was stored at 0°C for 3 days after which it was opened and weighed to determine the amount of fluid lost during vacuum packaged storage. The cut was then used for the determination of cooking loss at 60, 70 and 80°C respectively. Six pieces (each about 25 mm thick) from each muscle sample were put into separate plastic bags, cooked for 60 min at the respective temperatures (two sample pieces per temperature) without the addition of any fluid, and fluid loss as a result of cooking determined by mass. The anterior pieces were subjected to 60°C, the posterior pieces to 80°C and the middle to 70°C. The water-holding capacity was determined from the fluid loss from four small samples of cooked muscle placed between filter papers, as the water holding capacity of the cooked meat could give an indication of the juiciness of the meat. Each sample was subjected to a pressure of 1 metric ton in a Carver Press for 1 min. The difference between the original and subsequent masses was calculated and expressed as a percentage of the initial mass. Cooked samples were allowed to cool to room temperature, after which samples were taken parallel to the fibre direction with a cork borer (12,5 mm diameter). The force necessary to shear the meat perpendicular to the fibre direction, was determined using an Instron Materials Testing Machine, fitted with a Warner-Bratzler measuring device.

Statistical analysis of the data was done using Student's t test (unpaired observations). Values of $P <$ 0,05 were considered to be significant.

Results

The results are presented in Tables 1 and 2 with all the available data of all the pigs taken into account. However, in Table 3 the results of the pH values were also analysed excluding the carcases showing DFD characteristics, i.e. a muscle pH value 24 h post mortem greater than 6,00.

Halothane test

The halothane test applied at 7 – 9 weeks, and the halothane test at 21 weeks of age both identified 30 normal and 17 stress susceptible pigs. However, three of the initially normal pigs died during the halothane anaesthesia at 21 weeks of age, and were subsequently reclassified as being stress susceptible. Of the 17 stress susceptible pigs identified at 7 – 9 weeks, three survived the halothane anaesthesia at 21 weeks of age, and were therefore reclassified as being normal.

Growth rate

The average mass of the stress susceptible pigs was generally lower than that of normal pigs during the growth period (Table 1). Although generally not significant, the difference at 12 weeks was significant (P $<$ 0,05). The average daily gain (ADG) of the stress susceptible pigs was also not significantly different to that of normal pigs (Table 2). The difference in feed conversion ratios (FCR) between the two groups of pigs was also not significant.

Carcase characteristics

Although the difference between the hot dressing percentages of the normal and stress susceptible pigs was not significant, the dressing percentage (cold mass) of the stress susceptible pigs was significantly more ($P <$ 0,01) than that of the normal pigs (79,95% vs 77,70% respectively). The average carcase length of the stress susceptible pigs (94,92 cm) was less than the average carcase length of the normal pigs (97,58 cm), but the difference was not statistically significant. The percentage difference between hot and cold dressing percentages (2,24%) was also smaller in stress susceptible pigs than in normal pigs (2,76%) although not significantly so. However, stress susceptible pigs had a significantly ($P <$ 0,01) lower backfat thickness (1,58 cm) than normal pigs (2,10 cm) (Table 2).

Table 1 Mean values, standard deviations (*SD*) and levels of significance (*t* test) between the mean live masses of normal and stress susceptible South African Landrace gilts at ages 12 – 21 weeks

Parameter	Age Weeks	Normal Mean (*SD*)	n^a	Stress susceptible Mean (*SD*)	n^b	Significance level (P)
Live mass	12	30,71 (3,58)	28	27,29 (5,62)	17	0,0299
Live mass	13	35,13 (4,22)	28	32,00 (5,64)	17	0,0549
Live mass	14	39,20 (6,43)	30	36,94 (6,25)	17	0,2449
Live mass	15	43,35 (6,78)	30	42,12 (6,90)	17	0,5569
Live mass	16	48,43 (7,86)	30	46,53 (6,71)	17	0,3848
Live mass	17	54,13 (8,34)	30	52,15 (7,84)	17	0,4191
Live mass	18	59,62 (8,55)	30	58,03 (8,25)	17	0,5348
Live mass	19	64,00 (8,84)	30	62,94 (7,70)	17	0,6699
Live mass	20	69,55 (9,54)	30	69,42 (9,34)	13	0,9678
Live mass	21	75,07 (8,90)	30	76,67 (8,96)	9	0,6408

[a] where $n < 30$, values were not available
[b] where $n < 17$, values were not available

Meat characteristics

Fifteen minutes post mortem the pH value of the stress susceptible group (6,23) was significantly lower ($P <$ 0,05) than the pH value of the normal group (6,41). The post mortem pH values (30, 45 and 60 min) of the stress susceptible group were all significantly lower ($P <$ 0,01) than that of the normal group. The average pH value 30 min post mortem of the normal group was 6,37, and that of the stress susceptible pigs 6,13. The average pH value of the stress susceptible group was 6,01 at 45 min post mortem, and 5,86 at 60 min post mortem, and those of the normal pigs 6,32 and 6,39 respectively. Twenty-four hours post mortem the stress susceptible pigs still had an average significantly lower ($P <$ 0,01) pH value (5,62) than the normal pigs (5,92), and the respective pH values were both below 6,00 (Table 2). These values, however, also include the pigs with DFD characteristics, i.e. a pH level 24 h post mortem greater than 6,00 (Newton & Gill, 1981). Excluding these pigs for the evaluation of the pH values, the same trend was found as with the inclusion of the DFD carcases, except that with the exclusion of the DFD carcases, no significant difference was found between the 24 h post mortem pH values of the normal (5,72) and the stress susceptible (5,57) pigs (Table 3).

More fluid was lost during vacuum packaging of samples from stress susceptible pigs (5,52%) than from normal pigs (4,87%), although the difference was not significant. The percentage cooking loss of the meat from stress susceptible pigs (18,29%) was greater than that of meat from normal pigs (18,12%) at 60°C, but less at cooking temperatures of 70 and 80°C (30,20%; 35,02% vs 31,36%; 36,64% respectively) (Table 2). None of these differences were, however, significant. The water holding capacity of the stress susceptible pigs at the temperatures of 60, 70 and 80°C (48,93%, 41,54% and 37,11% respectively) were not significantly different from those of the normal pigs (48,15%, 41,40% and 36,66% respectively). The shear force values were lower for the meat from stress susceptible pig carcases (67,02N; 66,05N; 89,27N) than for meat from normal carcases (77,52N; 88,88N; 98,79N) at the three different temperatures (60, 70 and 80°C respectively); significantly ($P <$ 0,01) so at 70°C cooking temperatures. Hence, the meat from stress susceptible animals was generally more tender. No statistically significant differences were found between the stress susceptible (28,01 cm^2) and normal (29,07 cm^2) pigs in respect of muscle area (*M. longissimus thoracis*).

Table 2 Mean values, standard deviations (*SD*) and levels of significance (*t* test) between some growth, carcase and meat characteristics of normal and stress susceptible South African Landrace gilts

Parameter	Normal Mean (*SD*)	n^a	Stress susceptible Mean (*SD*)	n^b	Significance level (*P*)
Average daily gain (kg)	0,79 (0,18)	30	0,78 (0,18)	17	0,9003
Feed conversion ratio	3,17 (0,34)	29	2,98 (0,34)	17	0,0759
Dressing %					
(warm mass)	79,93 (2,53)	30	81,60 (2,65)	14	0,0542
(cold mass)	77,70 (2,44)	30	79,95 (2,51)	17	0,0046
% difference	2,76 (1,05)	30	2,24 (0,68)	14	0,0567
Backfat thickness (cm)	2,10 (0,58)	30	1,58 (0,48)	17	0,0020
Carcase length 1 (cm)	97,58 (4,04)	30	94,92 (6,01)	17	0,1107
Carcase length 2 (cm)	79,33 (3,68)	30	77,96 (4,68)	17	0,3047
pH value					
(including DFD)					
15 min p.m	6,41 (0,17)	30	6,23 (0,32)	17	0,0403
30 min p.m.	6,37 (0,17)	30	6,13 (0,31)	17	0,0066
45 min p.m.	6,32 (0,17)	30	6,01 (0,31)	17	0,0004
60 min p.m.	6,39 (0,16)	12	5,86 (0,28)	17	0,0001
24 h p.m.	5,92 (0,28)	30	5,62 (0,37)	17	0,0057
Drip loss (%)	4,87 (1,72)	30	5,52 (2,17)	17	0,3076
Cooking loss (%)					
60°C	18,12 (4,33)	30	18,29 (3,78)	17	0,8869
70°C	31,36 (2,62)	30	30,20 (4,22)	17	0,3153
80°C	36,64 (1,91)	30	35,02 (4,12)	17	0,1395
Water holding capacity (%)					
60°C	48,15 (5,14)	30	48,93 (3,20)	17	0,5435
70°C	41,40 (5,29)	30	41,54 (3,33)	17	0,9124
80°C	36,66 (4,11)	30	37,11 (3,51)	17	0,7063
Shear force (N)					
60°C	77,52(25,84)	30	67,02(13,02)	17	0,0859
70°C	88,88(36,99)	30	66,05(15,75)	17	0,0081
80°C	98,79(26,85)	30	89,27(19,52)	17	0,1694
Muscle area (cm^2)	29,07 (3,94)	30	28,01 (6,74)	17	0,5600

p.m.: post mortem
a: where $n < 30$, the values were not available
b: where $n < 17$, the values were not available
DFD: Carcases with a 24 h pH value greater than 6,00 in the *M. longissimus lumborum*

Table 3 Mean values, standard deviations (*SD*) and levels of significance (*t* test) between pH values of normal and stress susceptible South African Landrace gilts, excluding any DFD[c] carcases

Parameter	Normal Mean (*SD*)	n^a	Stress susceptible Mean (*SD*)	n^b	Significance Level (*P*)
pH value					
15 min p.m.	6,41 (0,21)	17	6,20 (0,30)	16	0,0293
30 min p.m.	6,35 (0,21)	17	6,10 (0,29)	16	0,0064
45 min p.m.	6,32 (0,21)	17	5,98 (0,29)	16	0,0005
60 min p.m.	6,40 (0,20)	8	5,80 (0,19)	13	<0,0001
24 h p.m.	5,72 (0,18)	17	5,57 (0,30)	16	0,0875

p.m.: post mortem

a: where $n < 17$, the values were not available

b: where $n < 16$, the values were not available

c: carcases with a 24 h pH value of greater than 6,00 in the *M. longissimus lumborum*

The parameters were also statistically evaluated after the DFD carcases were excluded. No changes were found in significance between stress resistant and stress susceptible pigs, except for the mean shear force value of the muscle cooked at 60°C. In this case the muscle of the stress susceptible pigs was more tender than that of the stress resistant pigs ($P < 0,05$; results not shown).

Discussion

Differences in classification of pigs as being normal or stress susceptible have been reported in the literature (Webb & Jordan, 1978). They found a 9% disagreement between repeated halothane tests after a 20-day interval, in which pigs initially classified stress susceptible, were classified as being normal during the second halothane test. A dose/response relationship was found in pigs using an intravenous halothane test, only after a certain threshold was exceeded, and this threshold varied between individual pigs (Gregory & Wilkins, 1984). These researchers also speculate that by using the conventional halothane test, stress susceptible pigs could produce a mild acidosis response, which need not be expressed as a reaction of limb rigidity, and the pig thus being classified as normal. Differences in classification may thus occur, due to misclassification (Carden & Webb, 1984), or due to factors such as the variation in exertional, nutritional and/or health status of the pig (Marby, Christian & Kuhlers, 1981).

Webb & Jordan (1978) have shown that ADG and FCR were similar in stress susceptible and normal Pietrain/Hampshire pigs. A similar finding was obtained by Eikelenboom, Minkema, Van Eldik & Sybesma (1978) and Eikelenboom, Minkema, Van Eldik & Sybesma (1980) using Dutch Yorkshire and Dutch Landrace gilts, thus suggesting that at least in respect of ADG and FCR stress susceptibility was not a disadvantage.

However, Eikelenboom, Minkema & Van Eldik in an earlier study (1976), McGloughlin, *et al.* (1980) and Mitchell & Heffron (1981) found a lower ADG and FCR in stress susceptible Dutch and German Landrace pigs. Our results obtained in this study using South African Landrace gilts indicated no significant differences in ADG and FCR between stress resistant and stress susceptible pigs, corresponding with the results of certain studies (Eikelenboom, *et al.*, 1978; Webb & Jordan, 1978).

On the other hand stress susceptible Landrace pigs seem to share similar, and economically advantageous carcase characteristics. Stress susceptible Landrace gilts have a significantly lower backfat thickness and higher dressing percentage compared to stress resistant ones (Eikelenboom, *et al.*, 1976, Webb & Jordan, 1978; Eikelenboom, *et al.*, 1980; Jensen & Andresen, 1980; Schmidt, 1980). These characteristics also occurred in the South African Landrace gilts used in the present study, but did not occur in stress susceptible Pietrain/Hampshire crosses (Webb & Jordan, 1978) or Dutch Yorkshire pigs (Eikelenboom, *et al.*, 1978). Although the lower backfat thickness is regarded as a desirable carcase characteristic for pork production, it has been indicated that pigs with a lower backfat thickness are more prone to produce undesirable dark, firm and dry (DFD) pork (Heinze, Gouws & Naudé, 1984) which is extremely susceptible to microbial spoilage, leading to a short shelf life (Newton & Gill, 1981). Furthermore, stress susceptible Dutch Landrace pigs (Eikelenboom, *et al.*, 1978) had significantly less carcase mass loss during chilling, a finding supported by our study, while stress susceptible Yorkshire and Pietrain/Hampshire pigs did not (Eikelenboom *et al.*, 1978; Webb & Jordan, 1978). Meat from stress susceptible pigs is generally more tender, and significantly so at a cooking temperature of 70°C.

These advantageous carcase qualities of stress susceptible Landrace pigs are, however, offset by the rapid fall in muscle pH which occurs post mortem in these pigs, and which is characteristic of stress susceptible animals (Mitchell & Heffron, 1981). The rapid fall in muscle pH post mortem leads to the development of pale, soft, exudative (PSE) pork and a resultant loss in mass (Klingbiel, Naudé & Van Essen, 1976), undesirable colour and accumulation of undesirable fluid (Lister, Gregory & Warris, 1981).

In summary, results of the present study support previous data collected on the growth and carcase characteristics of stress susceptible Landrace pigs. In general, stress susceptible Landrace pigs do not have economically advantageous or disadvantageous growth characteristics. However, although certain carcase and meat quality traits of stress susceptible animals are superior to those of normal animals, the low pH value and resultant PSE meat neutralizes the advantageous carcase and meat characteristics such pigs possess. It is therefore, in the interests of the pig industry to reduce the incidence of stress susceptibility.

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