CORRELATED RESPONSES TO SELECTION FOR GROWTH AND LEANNESS IN SHEEP

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SUMMARY

Selection for high growth and low subcutaneous fat thickness provides a genetic option to address consumer demand for leaner sheep meat. However the full impact of this option on the efficiency of a meat producing enterprise can only be assessed when the correlated responses in other production traits are known.

Selection for and against live weight resulted in a direct response in live weight at the age of selection, and correlated responses in weights at other ages, including maturity. Selection for weaning weight increased appetite, growth and body fat in the young animal, independently of stage of maturity. It was proposed that these changes were largely a consequence of the effect of selection at an early age (eg weaning) on appetite, and that selection at later ages (eg yearling) would result in little variation in food intake, growth and compositional traits, after scaling for differences in mature weight. In a straight breeding system selection for weight, whether at weaning or later ages, had little effect on biological efficiency of the enterprise, although in a crossbreeding system selection for weight in the sire line increased biological efficiency.

Selection for high and low backfat in sheep resulted in direct responses in fat thickness, although the magnitude of the response in total carcass fat was less than predicted, due to a differential rate of response in individual fat depots. This change in fat partitioning may have implications for carcass quality at the lower levels of fatness. Information is still required on changes in feed intake and efficiency of growing animals, and maternal characters of ewes selected for low backfat. Correlated responses in reproductive traits differed between experiments, highlighting the need for replicated studies in other populations.

INTRODUCTION

Consumer demand for leaner meat has made reduction in carcass fat the principle objective for most meat producing species (Kempster 1989). A reduction in fatness can be achieved via a variety of genetic and management options. In ruminants there is limited scope for nutritional manipulation, particularly under the extensive grazing conditions which are common in Australia. Genetic change provides a permanent means of manipulating carcass composition and a means which is likely to be more cost effective.

The combination of fast growth rate and leanness has been identified as a desirable breeding objective for terminal sire meat sheep breeds (Atkins 1987), although the situation is less clear for maternal sheep meat breeds (Fogarty 1987). At the same age, measures of both body weight and backfat thickness have a moderate to high heritability (Wolf et al 1981) and are positively correlated (Simm & Dingwall 1989), although when backfat thickness is adjusted for weight the genetic correlation was low (Atkins, K.D., pers. com.). Therefore use of live weight and weight adjusted backfat thickness in a selection index should allow genetic progress towards a larger leaner carcass (Simm & Dingwall 1989). However, the full impact of such indexes on the efficiency of a meat producing enterprise can only be assessed when the correlated responses in other production traits are known. This paper reviews the correlated responses in
productive traits to selection for both body weight and leanness in sheep.

Given the correlated responses in mature weight to selection for body weight, comparisons between selection lines at the same weight, or age, largely reflect differences in stage of maturity. This review focuses on the correlated responses to selection for weight that occur after scaling for genetic differences in mature weight (Taylor 1980).

CORRELATED RESPONSES TO SELECTION FOR WEIGHT

Davis (1987) reviewed seven single trait selection experiments in which selection had been for some measure of growth. In all experiments there was a response in the desired direction of 0.5 to 1% of the control mean per year, which was in good agreement with predictions from the base population estimates of heritability. In experiments in which there were both high and low selection lines and a control line the response to weight selection was symmetrical.

There have been few detailed investigations of the correlated responses in weight selection lines. Lines that have been extensively studied are the high and low weaning weight lines, established at Trangie in Australia (Pattie 1965a). This section of the review will concentrate on the results derived from these Trangie lines. However, for more robust conclusions to be drawn on the correlated responses to weight selection there is clearly a need for more extensive study of other weight selection lines.

The Trangie weaning weight selection lines were established from a base population of Peppin Merinos in 1951 (Pattie 1965a). Control flocks were first sampled from the base population and the selection lines formed from the 10% of ewes and 4% of rams with the highest and lowest unadjusted weaning weights. For the first six years replacements for the high and low lines were selected solely on unadjusted weaning weight, after which the selection criterion for replacements was changed to weaning weight adjusted for age and birth type.

Food intake and efficiency. Correlated responses in food intake and food efficiency in the Trangie lines were first examined by Pattie and Williams (1966), using a seven week growth period. The lines differed in mature weight by a factor of 1.3, hence at the same age the high weaning weight line would be expected to have a higher food intake and gross food conversion efficiency than the low weaning weight line. Pattie and Williams (1966) confirmed differences in food intake, but not in gross food conversion efficiency, indicating that at least some variation in feeding and/or efficiency traits was independent of mature weight. A more detailed examination of the food intake patterns in these lines by Thompson et al (1985a), revealed that the high line had a greater mature food intake than the low line, and that this difference was markedly reduced after scaling for mature weight. However even after scaling, there were differences in early food intake, the high line having a 50% greater scaled appetite. Selection for weaning weight effectively bent the food intake by age curve, with the greatest divergence between the lines occurring at weaning. Selection at later ages (eg yearling, or at maturity) might be expected to have less effect on appetite, as selection would generally occur well after the age at which the animals had reached their mature food intake.

The study by Thompson et al (1985a) also showed little difference between the high and low weaning weight lines in the exponential rate at which food was converted to live weight, or in gross food conversion efficiency ratio. The former is potentially a more useful measure of efficiency as it is scaled for differences in mature weight and free of the live weight maintenance component. The latter however is commonly the only measure of food efficiency considered in
most studies. The similarity between the lines in gross food conversion efficiency supported the earlier similar observation by Pattie and Williams (1966). Brown and Frahm (1975) also found no difference in post-weaning gross food conversion efficiency in strains of mice selected for pre-weaning growth rate. In contrast, results from mice studies in which selection has been for some form of post-weaning growth have generally resulted in an increase in post-weaning gross food conversion efficiency (see review by Roberts, 1979). An explanation for the apparent departure from this expectation was proposed by Thompson et al (1985a). Gross food conversion efficiency ratio is a function of the animal's appetite, maintenance efficiency and the exponential rate at which animals convert food to body weight (Parks 1982). Since in mature animals, food intake is proportional to the 0.73 exponent of weight, a genetic increase in mature weight will result in a proportionally smaller increase in mature food intake. This results in an increase in the ratio of mature weight to mature food intake, or maintenance efficiency, and a higher gross food conversion efficiency at the same age. Thompson et al (1985a) proposed that in the Trangie lines, the greater appetite in the high line effectively offset any advantage from the higher maintenance efficiency, with the net result that there was no difference between the lines in gross food conversion efficiency.

Live weight. In all weight selection experiments reviewed by Davis (1987), there were correlated responses in live weights at other ages, including maturity, confirming the positive realised genetic correlations between live weights at different ages. However, in most experiments immature and mature weights have been recorded only infrequently, making it difficult to assess the effect of weight selection on the shape of the growth curve. In the Trangie selection lines, the increase in appetite associated with selection at weaning bent the growth curve. Hence, after scaling for mature size, the high line matured at a faster rate than expected (Thompson et al 1985a).

Body composition. Correlated responses in body composition to selection for weight have only been studied in detail in the Trangie weaning weight lines. The early study by Pattie and Williams (1966) found that after adjusting for carcass weight, there were no differences between the lines in carcass composition. This differed from results from between breed studies which show larger mature weight breeds, or strains, have a less mature body composition at the same weight (eg Butterfield et al 1983). It suggested that the weaning weight lines differed either in their mature body composition, and/or in the rate at which tissues matured in the body.

A more detailed study by Thompson et al (1985b), revealed no difference between the lines in fat and muscle proportions at maturity, although there was an unexpected increase in the proportion of bone in the body of the high line. As mature weight increases, a small increase in the proportion of bone relative to mature weight can be argued on scaling alone; the proportional changes observed however were greater than would be expected from the between species relationship for mature bone weight and mature live weight reported by Prange et al (1979). It is possible that selection for high weaning weight in a dry pasture environment, where body fat levels of lambs would be low, may have indirectly favoured a higher proportion of bone.

In the Trangie lines there were also correlated changes in the rate at which tissues in the body matured relative to the rate at which live weight matured. Fat matured earlier and bone later in the high compared with the low weaning weight line. Thompson et al (1985b) suggested the earlier maturing pattern for fat in the high line could be due to increased lamb milk consumption and fat deposition pre-weaning. As there were similar proportions of fat at maturity, line differences in maturing patterns for fat resulted in a cross-over effect in
body composition and this occurred at around 30 kg live weight, consistent with
the results of Pattie and Williams (1966).

If the difference in maturing patterns of tissues between the Trangie lines was
simply a function of the increased milk consumption, giving rise to increased
fat deposition pre-weaning, it might be expected that selection for weight at
later ages (e.g. yearling) would have little effect on both tissue maturing
patterns and mature composition. Changes in composition from selection for later
weights would then conform to the general pattern observed between breeds, where
breeds can vary markedly in mature weight, but have similar composition at the
same stage of maturity (Butterfield et al 1983).

Even though selection for weaning weight increased the total weight of fat in
the body, there was little effect on either the partitioning of fat in mature
animals, or the maturing patterns of individual depots relative to total body
fat (Thompson et al 1987). Similarly, there was little difference in muscle
(Perry et al 1989) or bone distribution patterns, or in bone shape adjusted for
bone weight within the carcass (Perry 1989). The fact that weight selection had
little effect on the partitioning/distribution patterns within the fat, muscle
and skeletal systems suggests that during development these tissues responded to
a similar sequence of growth impulses, regardless of final mature weight.

Reproduction. The correlated changes in reproduction due to selection for weight
have generally been variable, and the net effects small. In the Trangie weaning
weight lines, analysis of the first 10 years data showed that selection for high
weaning weight resulted in a marginal increase in fertility and number of lambs
born per ewe joined, although a slight decline in lamb survival and rearing
ability meant that there was no difference between the lines in number of lambs
weaned per ewe joined (Pattie 1965b). Subsequent analyses by Davis (1987), which
included more data, showed that as weaning weight increased, so too did lamb
survival. This effect was such that in later years there was a dramatic decrease
in the viability of the low weaning weight line. A possible explanation for this
is that these lambs had become so small that they had reached a biological
threshold below which survival was difficult. Clarke (1986) and Lasslo et al
(1985) reported an increase in prolificacy with selection for weight, although
in the latter study this was offset by a decline in fertility and rearing
ability, with the net effect being a decline in the number of lambs weaned per
ewe joined.

Wool production. Selection for weaning (Pattie 1965b, Clarke 1986, Davis 1987)
or yearling weight (Turner et al 1970, Clarke 1986) has in general led to
slightly increased fleece weights. If the increases in live weight were
accompanied by proportional increases in mature food intake, it can be
calculated that in five of the six experiments referred to by Davis (1987), the
small increase in wool production would be more than offset by increases in food
intake, and that efficiency of wool production would decline with selection for
body weight.

Enterprise efficiency. Two issues which need to be considered are the impact of
weight selection on the biological efficiency of converting food to lean tissue,
and the effect of weight selection on carcass composition. Biological efficiency
of a meat producing enterprise is given as the ratio of output, (in units of
weight of lean from both the progeny and cull ewe), to input, (in units of food
consumed by both the progeny and ewe). The effect of weight selection on
biological efficiency will depend upon the production system being evaluated.
Effects on biological efficiency, mediated via change in mature weight, were
simulated using the model of Thompson and Barlow (1986). It was estimated that a
25% increase in mature weight in a straight breeding system with annual lambing,
was associated with only a 4% increase in biological efficiency. This small increase in efficiency was solely due to seasonal moulding of reproduction, which advantaged the larger mature size line. A large increase in appetite, as observed in the Trangie lines, would be expected to have little effect on the biological efficiency of meat production, however it would reduce the time to reach slaughter weight, which may be critical in a system with seasonal oscillations in pasture quantity/quality.

In a crossbreeding system utilizing a large mature weight sire line crossed with smaller mature size dams, the change in biological efficiency resulting from selection for weight in the sire line is much larger (Taylor et al 1985). Again using Thompson and Barlow's (1986) model, the increase in biological efficiency associated with a 25% increase in mature weight of the sire line, was estimated to be 7%. In a second cross system, where heterosis for reproduction is also involved, biological efficiency would be further increased.

At constant slaughter weight, selection for weight results in a marked reduction in fatness, via a reduction in stage of maturity at slaughter. As the curvilinear relationship between biological efficiency and stage of maturity at slaughter is relatively flat in the region of 40 to 85% of mature body weight, the slaughter of weight selected animals at constant weight will result in only a small reduction in the biological efficiency of meat production, although a large reduction in carcass fat. Advantages of weight selection are therefore likely to depend more upon the price premiums being paid for particular fatness/carcass weight combinations than changes in biological efficiency.

CORRELATED RESPONSES TO SELECTION FOR LEANNESS

Until recently there has been little information available on the correlated responses in productive traits to selection for leanness in sheep. A major obstacle has been the lack of suitable objective techniques for measuring leanness in the live animal. However, in recent years ultrasonic scanners have been used successfully to obtain objective measurements of backfat thickness in live sheep (Simm 1987).

Two selection experiments for high-and low backfat thickness in sheep commenced in New Zealand in the last 14 years and results on correlated responses are beginning to come to hand. High and low backfat Coopworth lines were established at Invermay in 1980 with the initial screening of lambs from eight commercial flocks. After removal of the controls, 12% of the fattest and 12% of the leanest ewes, based on weight adjusted ultrasonic fat thickness, were selected from each of four flocks. A similar procedure was used to select the control rams and 4% of the fattest and 4% of the leanest rams from an additional four flocks. Thereafter replacement rams and ewes were selected within flocks on the basis of weight adjusted ultrasonic fat thickness at the 12th rib site, measured at six and eight months in rams and ewes, respectively (Fennessy et al 1987). In 1988, the selection procedure was changed so that current selections are now based on BLUP breeding values and scanning at both the C and GR sites at higher liveweights (Fennessy et al 1989).

Backfat selection lines were also established at Massey University from a population of Southdown sheep, in which ewe selections were done on nine month weight adjusted ultrasonic measurement of fat thickness at the 12th rib, expressed as a percentage deviation of individuals from a double-log regression line. Rams selections were done on an initial screening at nine months with a final measurement at 16 months (Solis et al 1990). The Massey lines did not include a randomly bred control.
After initial screening and a further eight years of selection at Invermay, the high line had a three fold increase in ultrasonic backfat depth relative to the low line (ultrasonic fat depth at the C site of 4.9 Vs 1.7 mm for the high and low backfat lines, respectively, McEwan et al 1990a). The divergence between the lines was highly asymmetric, most of the response occurring in the high line and little in the low line over the last six years. Factors which may have contributed to this recent slow response in the low line include genetic drift and reduced variation, with perhaps the most likely being the limit of the ultrasonic machine to accurately measure backfat depth at low levels of fat, thereby creating an artificial plateau to selection (McEwan et al 1990a).

Kadim (1988) reported that after seven years of selection the high backfat line at Massey had 1.6 times the ultrasonic backfat depth of the low backfat line (ultrasonic fat depth at the C site of 9.8 and 6.0 mm for the high and low lines, respectively), although this sample may be biased as some rams had been culled and replacement rams selected, prior to measurement.

Food intake and efficiency. Metabolizable energy intake is partitioned between heat and energy retained in fat and protein in the body. As discussed by Webster (1989) an increase in lean content may not necessarily result in an increase in the efficiency of the animal. Simpson et al (1978) showed the higher lean content of deer compared with lambs was due to a greater heat loss, with no change in the efficiency of converting metabolizable energy to lean. Similarly in pigs an increase in the lean content can be achieved via a lower food intake (Fowler et al 1976). Obviously the most desirable mechanism for increasing lean content of lambs is to change the partitioning of nutrients towards lean rather than fat without any change in either metabolizable energy intake or heat production in the animal.

There is no information on correlated responses in long-term patterns of food intake, food conversion efficiency, or energy balance to selection for backfat. However a long-term growth and compositional study using the Invermay lines has recently been commenced at the University of New England, Armidale.

Live weight. Preliminary results on correlated responses in the Invermay lines show a marked change in birth weight (Fennessy et al 1989). The low line had a higher birthweight than the controls, which were higher than the high backfat line. Although the difference between the low and the control lines appears to have stabilized, birth weight in the high line has continued to decline with selection. A negative genetic relationship between backfat depth and birthweight was perhaps unexpected, but has recently been confirmed by McEwan J.C. (pers. com.) from half-sib analyses. The effect of selection for low backfat thickness on muscle growth and fibre differentiation and its relationship to changes in birth weight is presently the subject of further studies at Otago University in New Zealand (McEwan J.C. & Harris A.J., pers. com.). In contrast the Massey lines showed no change in birth weight (Solis-Ramirez et al 1990), highlighting the variation between experiments in correlated responses to backfat selection.

In the Invermay experiment there has been little correlated change in weaning weight, 15 month weight, or mature weight between the low backfat and control lines. However in the high backfat line, the decline in birth weight was also present in later weights, although the effect was somewhat reduced (Fennessy et al 1989). For the Massey lines, Kadim et al (1988) reported no differences in the carcass weight of 15 to 18 month old rams, or in pre-mating ewe live weights (Purchas R.W., unpub. data, cited by Kadim et al 1988).

Body composition/meat quality. Preliminary results from studies on correlated responses in compositional traits have been reported for both the Invermay and
Massey experiments. McEwan et al (1990b) reported on a growth study in which a total of 182 lambs from the 3 lines, born in 1986 and 1987 were slaughtered at 3 monthly intervals, from 3 to 18 months of age. The allometric growth coefficients for carcass water and protein weight relative to carcass weight were greater in the low and control lines, compared with the high backfat line. McEwan et al hypothesized that since selection for high and low backfat thickness affected the allometric growth coefficients, it was likely either that selection was acting to alter some hormone/receptor mechanism that was expressed throughout the animal's life, or alternatively a biological switch had been changed during embryonic development which had subsequently altered the postnatal growth pattern of tissues. When adjusted to the mean carcass weight, the lean line had 21% less chemical fat weight in the carcass than the high line (McEwan et al 1990b). In a study of 78 rams from the Massey selection lines, Kadin et al (1988) reported that over a restricted weight range the low line had a 16.5% decrease in carcass fat weight compared with the high backfat selection line.

If backfat depth is considered to be a one-dimensional measure of carcass fatness, then the reductions in carcass fat weight in the low relative to the high backfat lines in both the Invermay and Massey experiments, are less than expected from the differences in backfat depth between the lines. This suggests that the same proportional change is not occurring in all depots in the carcass. There is little information on genetic relationships between fat depots within the body. The limited reports in the literature indicate that although correlations are generally positive, they vary considerably in magnitude (Wolf et al 1981, Olsen et al 1976). This suggests that selection for a decrease in one depot (such as subcutaneous fat) may not result in equivalent changes in other carcass and non-carcass depots.

Using data from the study by McEwan et al (1990b), a preliminary analysis showed differences in the proportional reduction in the weight of fat in individual depots in the low relative to the high lines. The greatest decrease in fat weight between the lines occurred in the subcutaneous, kidney and channel and omental depots (36, 33 and 39% respectively), with the smallest decline in the intermuscular depot (18%). As expected the differential reduction between depots resulted in large differences in fat partitioning between the lines. At the same total fat weight (ie the sum of the omental, kidney and channel, subcutaneous and intermuscular depots), selection for low backfat resulted in a decrease of 3, 4 and 10% in the subcutaneous, kidney and channel and omental depots respectively, and a 14% increase in the intermuscular depot. Similarly, in a study on fat partitioning in the Massey lines, Kadin et al (1988) reported that when adjusted to a constant total half carcass dissectible fat weight, the low relative to the high backfat line had 5 and 28% less subcutaneous and intramuscular fat, 7% more intermuscular fat and no change in the weights of internal fat depots (ie kidney and channel and omental fat).

Results from the Invermay and Massey selection experiments indicate that selection based on ultrasonic backfat measurements can successfully be used to achieve substantial reduction in carcass fat. It is important however that changes in carcass traits be monitored, as the benefits of a reduction in the subcutaneous depot may be somewhat offset by a change in fat partitioning. As consumers become more discriminating with respect to fat, the proportional increase in intermuscular fat could pose a problem. Perhaps of greater concern is the large decrease in intramuscular fat reported in the Massey low backfat line. Although intramuscular fat content is seldom listed as a consumer requirement for sheep meats, studies in the US (Tatum, Smith and Carpenter 1982) and Denmark (Sorensen and Buchter 1985) have indicated that palatability of meat can decline when intramuscular fat levels are very low. However this may be in
part a function of traditional cooking procedures used, as venison has very low intramuscular fat content (Wallace and Davies 1985) and does not suffer a palatability problem.

Objective measures of meat quality of carcasses from the high and low Massey lines were examined by Kadim (1988). There were no differences between the lines in all the meat quality parameters examined, which included Warner Bratzler shear values, sarcomere length, reflectance, expressed juice, cooking loss and final pH. However as the meat samples used by Kadim (1988) were from carcasses heavier than 16 kg and with 12th rib fat depths in excess of 4mm, it is unlikely that quality problems associated with ultra-lean carcasses, would have been evident in this study. The experience of the United Kingdom pig industry is relevant here, where the bulk of published research work on pig meat quality was carried out on carcasses with fat levels much higher than the ultra-lean carcasses of today. Whereas this research showed little relationship between fatness and eating quality, there is an increasing incidence of meat quality problems among the ultra-lean carcasses at the leading edge of the frequency distribution (Kempster 1989).

In addition to further information on the correlated responses in carcass quantity and quality traits, we need a greater understanding of the correlated responses that occur in physiological traits of the animal. A number of studies in sheep and cattle have reported that breeds having a higher milking potential tend to have a greater proportion of fat in the non-carcass depots (Kempster 1980). In an attempt to provide a physiological explanation for the differences in fat partitioning in sheep, Wood et al (1980) proposed that those breeds with a high reproductive rate and high milk production require larger proportions of non-carcass fats for the maintenance of pregnancy and lactation. The effect of pregnancy on fat partitioning was demonstrated in a recent study by Saka, K., Thompson J.M. and Hinch G.N. (unpub. data), in which pregnant and non-pregnant Merino ewes were maintained at the same maternal body weight during late pregnancy. There was no change in total body fat, but the pregnant ewes had a lower proportion of fat in the kidney (16%) and omental (13%) fat depots and more in the subcutaneous depot (18%), than non-pregnant ewes. Since comparison at the same total fat weight, a change in one depot will be mirrored in other depot/s and it is not possible to ascribe the primary effect. However the result is consistent with pregnancy causing greater mobilization of the non-carcass depots.

Unfortunately most studies on fat partitioning in sheep have not been accompanied by comparative data on milk production. One exception to this was the study of Geenty et al (1979), where breeds with a greater proportion of fat in the non-carcass depots also had a greater milk production (Geenty and Jagusch 1974). Butler-Hogg et al (1986) also concluded that differences in fat partitioning between breeds of similar mature size were related to milk production potential.

Given the possible relationship between fat partitioning and the ewe’s ability to withstand high pregnancy and lactation load it is important that high and low backfat selection lines be examined for correlated responses in maternal traits. The possibility that selection for low backfat could reduce internal fat depots and result in deleterious changes in maternal traits needs to be considered before low backfat selection is widely incorporated in the breeding objective for maternal sheep breeds. As already mentioned, an experiment to examine correlated responses in feeding, growth; composition and maternal traits has recently commenced in Armidale using sheep from the Invermay lines, in which changes in fat mobilization during pregnancy and lactation will be measured using a Whole-Body CAT-Scanner.

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Reproduction. Correlated responses in maternal traits could be all the more important as a result of correlated changes in ovulation rate in the Invermay lines. Ewes from the lean and fat lines have shown a 10 to 20% increase and decrease respectively in ovulation rate relative to the controls (Fennessy, P.F. pers. com.). In contrast, the Massey lines have shown no divergence in fertility (Solis-Ramirez et al 1990). The difference between experiments highlights the variable nature of correlated responses to selection for backfat in different sheep populations.

Enterprise efficiency. The impact of selection for low backfat on biological efficiency of the enterprise cannot be estimated until data is available on food intake patterns and energy balance.

CONCLUSION

A number of experiments have demonstrated that selection for increased weight in sheep will increase live weight at the age of selection, although there have been few investigations of correlated responses in feeding, growth, compositional and efficiency traits. An exception are the Trangie high and low weaning weight lines which have shown that apart for small deviations in early feed intake, growth, and compositional traits, most of the changes associated with weight selection were proportional to the changes in mature weight.

Results from two experiments have demonstrated that selection for high or low backfat thickness can produce genetic change in backfat and carcass fatness. There was some agreement between studies on the associated changes in fat partitioning, although this was not the case for other traits such as birth weight and reproduction. The differences between experiments highlights the variable nature of correlated responses to selection for backfat in different sheep populations.

The robustness of conclusions as to correlated responses to selection for either weight or low backfat are limited by the small number of selection lines available for study. There is a need for more selection lines to be developed, or where lines already exist, for detailed studies in correlated responses to be undertaken.

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REFERENCES
