PIG GROWTH PATTERNS

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Presumably, populations can be characterized by their growth patterns. Yet growth is a complicated biological phenomenon with no adequately defined direct measure. Growth may be considered as a combination of physical processes, cell size and cell number, or chemical changes which are responsible for physiological maturation. Thus, growth may be considered from at least two aspects: 1) an increase in body mass with time and 2) changes in form or composition resulting from different growth rates of component parts. The increase in body mass may be divided by time sequence, e.g., prenatal, postnatal to weaning, weaning to slaughter and growth in the breeding herd (slaughter weight to maturity). Generally, composition is thought of in terms of fat, bone, muscle, organs, etc.

It has been generally accepted that individuals that grow more quickly and more efficiently are later maturing animals with heavier mature weights. These results are not necessarily undesirable since it would seem that such animals may be slaughtered at heavier weights (presumably with lean carcasses) resulting in less labor and overhead costs per kilogram of product.

However, for the breeding herd, heavy mature weights may be undesirable. If heavy mature weights result in delayed puberty there will be increased replacement costs and possibly increased generation intervals. Also an increase in mature size may adversely affect maintenance requirements of the breeding herd. The latter situation is of particular importance where reproductive rates are low and maintenance costs of the parental stock are a significant portion of the cost of production. Nevertheless, large mature size may be desirable if it is necessary for maximum production of offspring. Furthermore, the increased efficiency in production of slaughter animals may offset increased maintenance costs.

It appears logical to assume that a higher growth rate can be achieved by animals with a genotype for a larger mature size which implies larger maintenance costs for the breeding herd. Yet this also assumes that animals with such genotypes will, in fact, achieve large phenotypes. This appears inevitable if animals are fed ad libitum for significant portions of their adult life. Presumably this would be the case for the grazing ruminant. However, if feed intake is controlled throughout the reproductive life such that individuals markedly fail to reach their genetically determined mature size and yet still produce effectively, then the undesirable consequences of selection for rapid growth (and large mature weight) will be averted. Thus, one could select for rapid early growth without fear of the consequences of mature size. In swine, feed restriction, as commonly practiced, will limit mature size without any apparent reduction in productivity. Furthermore, this may suggest an area of research needing attention in grazing ruminants, i.e., means of limiting phenotypes of genetically large animals. Rate of growth seems of much more interest than mature weight since few animals (particularly in swine but probably in other species as well) reach mature weight. According to Brody (1927) swine will have achieved only about 80% of mature weight by 24 months of age. A very low proportion of animals are maintained longer than this. Additionally, if specialized female and male lines are developed, male lines can be selected for rapid growth and females may be selected to be small and thrifty.
With this prelude it seems appropriate to consider growth of swine in three time span categories, i.e., prenatal, birth to weaning and weaning to slaughter weight. Consideration of mature size does not seem appropriate since it is rarely achieved and virtually no data exist concerning it.

Prenatal Growth

Ullrey et al. (1965) reported a comprehensive study of the growth of the swine fetus. Growth curves for various measures are shown in figures 1 to 3. They represent mean values at 51, 72, 93 and 114 days of gestation. Skeletal measures and body length generally exhibited a linear relation with age. On the other hand, soft tissues, including body weight, increased in a curvilinear fashion with age. Yet even for the soft tissues it appears that growth after 72 days was nearly linear.

![Diagram showing growth curves for heart, kidney, and spleen.](image)

Figure 1. Prenatal growth of heart, kidney and spleen. Ullrey et al. (1965).

Several workers have shown a strong negative correlation between litter size and individual prenatal growth. The swine industry needs to be extremely careful about adoption of birth weights as a selection criterion. Since it is negatively correlated with litter size, such selection may result in selection against litter size. Further, the heritability is low and little progress can be expected. Yet emphasis on the trait will weaken the effort that can be expended on more important traits.
Figure 2. Prenatal growth skeletal growth. Ullrey et al. (1965).

Figure 3. Prenatal growth of body weight and length. Ullrey et al. (1965).
Preweaning Growth

Actually very little research has been reported on preweaning growth patterns. Whatley and Quaife (1937) reported on preweaning growth ranging to 10 weeks. Preweaning growth was curvilinear, yet from their graph (figure 4) it appears that preweaning growth could be divided into two distinct growth phases. If separated into growth before and after approximately 6 weeks, growth was essentially linear. This change in growth may be due to implementation of supplemental feeding at about 6 weeks of age. Ahlschwede and Robison (1971) suggested that the relation between direct genetic and maternal effects changes from positive to negative at about 3 weeks of age (the age at which supplemental feed was made available). Thus, it appears that preweaning growth is greatly affected by the practice of creep feeding. If preweaning growth is to be used as a measure of milk production, it appears that creep feeding should not be practiced or that weights taken before the initiation of creep feeding should be utilized. The data of Ahlschwede and Robison (1971) were utilized to construct preweaning growth curves (figure 5). In these data, growth was significantly curvilinear. For about the first 4 weeks growth was nearly linear. After this time growth rapidly accelerated. These data involve approximately 175 pigs each of the Duroc and Yorkshire breeds.

Figure 4. Preweaning growth of swine. Whatley and Quaife (1937).
Figure 5. Preweaning growth of swine. Adapted from Ahlschwede and Robison (1971).

It has been suggested by Revelle and Robison (1973) that preweaning growth may have an effect on female reproductive performance. They suggested that reduced preweaning growth would retard sexual maturation. Nelson and Robison (1976a,b) have shown, in both mice and swine, that females reared in large litters produced smaller litters than those reared in small litters. The importance of early environmental influences on performance late in life should not be overlooked. This implies that "potential" replacement gilts should be selected at birth and placed in an "optimum" rearing environment, e.g., 6 gilts per litter. Later selection would be on growth and backfat from this pool of potential replacements.

Widdowson (1968) reported that retarded growth influenced sexual maturation. In retarded rats the testes were large relative to the body but interstitial cells regressed with no signs of spermatogenesis. After an individual was returned to a normal growth pattern, the testes continued to grow but at a slower rate than the body. Hence, testes weight in relation to body weight decreased and was smaller than for "normal." Likewise in the female the uterus and vulva enlarged, primordial follicles developed and some became large and cystic but there were no signs of ovulation. Johnson et al. (1974) reported that testis size and function were related to preweaning growth in beef bulls. There is a paucity of knowledge concerning the effects of early growth on sexual maturation. This area needs extensive study.
Retardation of growth due to insufficient food sets off a highly complicated chain of responses. Some aspects of development continue relatively unaffected by retardation of somatic growth, whereas others keep more or less in step with the size of the animal. Rehabilitation of severely retarded pigs [5 to 6 kg (11 to 13 lb) at 1 year] is possible and the animals grow very nearly "normal" and body composition becomes "normal" (Lister and McCance, 1967).

Boaz and Elsley (1962) fed pigs to weight 30, 40 and 50 lb at 56 days. The growth curves from about 70 days, or from 50 to 200 lb were essentially the same. Growth patterns for the Light (31 lb) and heavy (45 lb) weaners are shown in figure 6. The lighter pigs at 56 days were slightly fatter but were not significantly so. The study of Nelson and Robison also showed that rate of growth on test was independent of weaning weight, i.e., there was no compensatory growth.

Figure 6. Growth of heavy and light weaners. Boaz and Elsley (1962).

Thus, it appears that early growth patterns may affect physiological maturation and carcass composition. It should be emphasized that, although animals may appear to grow the same after weaning and hence have small differences in final weights, certain physiological mechanisms may have been altered.

Postweaning Growth

Body weight. Among early attempts to describe body weight curves of swine were those of Bywaters and Willham (1935) and Ittner and Hughes (1938). Although
no mathematical expressions were derived, the fitted data were presented as in Ittner and Hughes (figure 7). Those data suggested a smooth curve with a linear growth between about 70 and 168 days with a slower growth rate after 168 days.

![Graph showing growth curve](image)

**Figure 7.** How 457 pigs grew up. Ittner and Hughes (1938).

Postweaning body weight curves have been reported by Donald (1940), Lush and Kincaid (1943), Taylor and Hazel (1955) and Abarca and Tapia (1963). The first two reports showed that a quadratic equation (non-linear) best fit the data. Yet Taylor and Hazel reported linear growth between 134 and 174 days of age with similar slopes for the faster growing one-third and the slower growing one-third of the pigs (figure 8). Growth between 53 and 346 days was reported to be linear by Abarca and Tapia.

More recently Quijandria and Robison (1971) and Standal (1973) have reported body weight curves. While in both cases the quadratic (non-linear) term was significant the percentage of the variation accounted for was only slightly larger than for the linear model (less than 1%). It is important to remember that significance is only a tool and some logic must be used. Significance does not necessarily imply importance. The data of Quijandria and Robison (figure 9) covered the ages 119 to 154 days with final weight of approximately 82 kg (181 lb), whereas Standal (figure 10) had an age range of 135 to 225 days with final weights up to 130 kilograms (287 lb). Using the data of Doornenbal (1971), with an age range of 78 to 210 days and a final weight of 130 kg (287 lb), a significant quadratic regression was calculated (figure 11). However, the quadratic term accounted for only about 1% of the variance. Further, while these results show different weights for boars and gilts the regression lines are nearly parallel. Recent work at Nebraska (P. J. Cunningham, personal communication) has shown a linear growth pattern also. However his data suggest different growth rates for boars and gilts. These results do not suggest the
same growth rate for all pigs but that the growth rate of the individual pig is linear. Thus adjustment factors must take into account the individual's growth pattern. Workers at Kansas have reported a correlation between ADG from 65 to 220 lb and ADG from 65 to 250 lb of .92. This suggests that the growth rate of animals may be adequately characterized by 220 lb. Thus, it appears that, in swine, the quadratic function is statistically significant but probably of little biological (practical) importance for postweaning gains to about 130 kilograms (287 lb).

Figure 8. Growth pattern for all pigs, high gaining one-third and low gaining one-third. Taylor and Hazel (1955).

Figure 9. Postweaning body weight curves. Quijandris and Robison (1971).

Figure 11. Postweaning body weight curves. Adapted from Doornenbal (1971).
Revelle and Robison (1973) suggest that rapid early growth may enhance reproductive performance. For example, rapid growth may reduce age at puberty. Hence, rapid growing gilts bred at a constant calendar age may be more sexually mature and produce larger litters than slower growing gilts.

Wallace et al. (1959), Buck (1963), Robison and Berruecos (1973) and Meeker (1973) have shown efficiency to decrease with increasing weights. Many authors have suggested a strong correlation between rapid growth and feed efficiency. Robison and Berruecos (1973) reported a genetic correlation of \(-.78\) between postweaning gain and postweaning efficiency (F/G). Further, several authors have suggested moderate heritabilities for postweaning gain. Robison and Berruecos have suggested larger heritabilities for gain if preweaning influences are removed, i.e., growth from 70 days to 94 kg (207 lb) is more heritable than lifetime average daily gain.

In the past, efforts to change the growth curve have been directed to a simple change in rate of growth. Based on the review presented here it seems logical to continue in this direction (at least for swine). Successful attempts to change rate of growth have been reported by Dettmers et al. (1965) who selected for low 160-day weight and by Craig et al. (1956) who selected for both high and low gain.

Body form. There are few reports in the literature concerning changes in body form. McMeekan (1940a) suggested that growth proceeded in an anterior to posterior fashion. Comstock and Winters (1944) measured pigs at 8 weeks and each 4 weeks until 230 lb or 180 days. They concluded that depth of body increased most followed by width of loin, body length and width behind the shoulders. Meeker (1973) stated that body measurements increased linearly from 230 to 290 pounds.

Backfat deposition. Since consumer preferences for less fat are quite marked, a discussion of growth would be incomplete without considering fat deposition. Furthermore, it has been assumed that lean deposition is more efficient than fat deposition. McMeekan (1940a, 1940b, 1940c) has postulated different growth rates for bone, muscle and fat during development. Bone and muscle develop first, then the rate of growth of these tissues slows down and fat deposition increases. Thus, it has been generally accepted that backfat deposition markedly accelerates at heavier preslaughter weights. It should be pointed out, however, that McMeekan's studies were based on an extremely small number of inbred Landrace. Furthermore, growth differences produced by altered nutritional regimes (such as McMeekan's) are likely to be different from those produced by genetic influences.

Hetzer et al. (1956), Noffsinger et al. (1959) and Pedersen (1973) measured backfat at weights ranging from 150 to 225 lb, 100 to 200 lb and 50 to 120 kg (110 to 264 lb), respectively. Hetzer et al. (figure 12) and Pedersen reported a linear relation between backfat and weight. Noffsinger et al. reported a significant quadratic effect; however, the addition of the quadratic (non-linear) term only increased the $R^2$ (accuracy of prediction) from 0.82 to 0.84. Thus the precision of predicting would be altered only slightly by using only the linear term. Recent reports (figure 13) by Quijandria and Robison (1971) and Standal (1973) have suggested that backfat deposition is essentially linearly associated with either age or weight. The slopes of the
regression lines for boars and gilts are nearly identical. Thus while gilts have more fat than boars, the rate of deposition is similar. Recent experiments at Nebraska have confirmed that backfat deposition is linear, but those results suggest different rates of fat deposition for boars and gilts. It should be emphasized that individuals have different rates of deposition but that for each individual this deposition is linear with weight. Adjustment factors for backfat must take into account individual differences in fat deposition.

Figure 12. Relation of backfat to weight. Hetzer et al. (1956).

Figure 13. Backfat deposition curves. Quijandria and Robison (1971).
Heritability estimates for backfat are moderate (Craft, 1958). Experiments by Hetzer and Harvey (1967), Gray et al. (1968) and Berruecos et al. (1970) have demonstrated the feasibility of reducing fat deposition by selection.

In discussing swine growth there is an interest in relative changes in component parts as well as in total body mass. Knowledge of the differential growth and development of the major constituents, protein, fat and ash, is essential. McMeekan (1940a,b,c) reported a major study on growth and development of the pig. In figures 14 and 15, McMeekan's results suggest a rapid acceleration of fat deposition relative to lean growth. Again, note that these data were based on a limited number of inbred Landrace. A major contribution to an understanding of this area was made by Doornenbal (1971, 1972). His results suggest that the growth pattern of protein is distinctly different from traditionally accepted growth curves where average daily gain of lean reaches a peak at 65 to 75 kilograms (143 to 165 lb). His data show an almost linear increase in average daily gain of protein and fat (figures 16 and 17) over the entire weight range [10 to 130 kilograms (22 to 287 lb)]. Furthermore, the protein in the cuts, ham, middle, shoulder and belly, remained practically constant, as a percent of total protein, over the entire range (figure 18). That is, there was little differential growth among the parts of the body. Average daily gain of fat increased in a linear fashion but slightly more rapidly than average daily gain of protein. Thus, the change in relative proportions between these two tissues was slow and gradual.

Figure 14. Rate of growth of skeleton, muscle and fat (grams per week). McMeekan (1940).
Figure 15. Composition of carcass with age. McMeekan (1940).

Figure 16. Average daily gain of fat, gm. "our data," Doornenbal (1972).
Figure 17. Average daily gain of protein (gm) and lean tissue (protein x 4). Doornenbal (1971).

Figure 18. Protein in cuts at increasing weights. Doornenbal (1971).
Percent fat increases and percent protein decreases linearly with increases in weight. Again the change in relation between fat and protein in the carcass is slow and gradual. If these results are expressed as a function of age, little change is noted since age and weight are essentially linearly related. These relationships will be shown later. Buck (1963) studying pigs at 150, 200 and 260 lb concluded that there was no change in % body composition as weight increased. Witte and Stringer (1969) reached similar conclusions for pigs weighing 220 to 300 lb while Otto (1966) concluded that, up to 286 lb, protein content of the carcass increased as weight increased. The results presented by Hinor (1971) suggest a slight decrease in lean weight gain between 57 and 125 kilograms (126 to 276 lb). However the graph for total weight of lean tissue shows a very nearly linear relation with live weight in this range. Meeker (1973) states that backfat and loin eye area increased linearly with weight, while meat quality and ham-loin percent did not change.

Osborne and Fliegel (1964) in a discussion of nitrogen and energy metabolism show little change in total energy deposited per day or in its distribution between fat and protein in pigs between 70 and 130 kg (154 and 287 lb) (table 1). They also show that even in very young pigs energy for fat deposition exceeds energy in protein deposition. There was no definite fattening and growing phase, i.e., no sharp limit above which feed energy is transformed to and laid down as fat. From about 80 to 130 kg (1976 to 287 lb) the metabolizable energy available above maintenance requirements rises without a corresponding rise in energy deposited as fat (table 2). After 130 kg (287 lb) feed intake ceases to rise; hence, metabolizable energy available for production falls slightly as a result of greater maintenance costs. The decrease in fat deposition during this period is greater than the reduction in energy above maintenance. This appears to be a decline in efficiency of energy utilization. It seems evident from these data that the decline in feed efficiency at heavier weights is due primarily to increased maintenance costs. However, there is an apparent reduction in efficiency of energy utilization per se after 130 kilograms (287 lb). It does not appear that the reduction in efficiency is due to increased fat deposition as has often been surmised.

Showing Doornenbal's data in terms of age, there is a linear relation of average daily gain, percent or weight of protein, fat and lean with age (figures 19, 20 and 21). There were significant quadratic effects for most measurements. However, the quadratic term increased the $R^2$ values by less than 1% for all but two traits and these were increased by less than 4%. Davey et al. (1969) and Davey and Morgan (1969) studied the effects of dietary energy and protein levels on growth of pigs from lines selected for high and low backfat. For all lines and diets studied the relation between separable lean or fat and age was nearly linear, at least until about 40 wks of age which represents live weights in the range of 130 to 150 kilograms (287 to 330 lb).

From these reports it appears that no marked change in protein or fat deposition occurs during the growth process prior to 130 kilograms (287 lb). There is gradual tendency for percent fat to increase and percent protein to decrease.
Table 1. Energy deposition in swine.

<table>
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<tr>
<th>Weight (kg)</th>
<th>Total energy (kcal/day)</th>
<th>Protein (as % of total)</th>
<th>Fat (as % of total)</th>
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Oslage and Fliegel (1965).

Table 2. Energy deposition and utilization in swine.

<table>
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<tr>
<th>Weight (kg)</th>
<th>Metabolizable energy available for production (kcal/day)</th>
<th>Fat deposited (kcal/day)</th>
<th>Total deposited (kcal/day)</th>
<th>Total deposition as % of metabolizable energy available for production</th>
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Oslage and Fliegel (1965).
Figure 19. Average daily gain of protein, fat and lean with age. Adapted from Doornenbal (1971, 1972).

Figure 20. Protein, fat and lean as % of empty body weight with age. Adapted from Doornenbal (1971, 1972).
Figure 21. Weight of protein, fat and lean with age. Adapted from Doornenbal (1971, 1972).

Conclusions

The economic importance of rapid growth in market hogs is clear. A number of studies have established a high relationship between rapid gains and efficient feed utilization. Also, a shorter feeding period increases throughout, reducing overhead and labor costs and reducing risk of loss from accident or disease. Moen and Standal (1971) slaughtered pigs at 90 (198 lb), 100 (220 lb) and 110 (243 lb) kg and reported no curvilinear effect on gain, efficiency or retail value. Postweaning rate of growth appears to be linear, or nearly so, for the ages and weights likely to be utilized in the near future. Since maternal maintenance costs are restricted by limit feeding of the breeding herd, high mature weights are not realized and are of little concern to swine programs. Furthermore, rate of growth is highly correlated with efficiency, therefore growth rate should be of major interest in swine breeding programs.

Backfat, fat or protein deposition in the carcass is nearly linearly associated with increases in weight or age. Because fat increases more rapidly than protein, there is a gradual change in their relative proportions. However, the decrease in feed efficiency with increasing weights is primarily due to increased maintenance costs and not to increased fat deposition.

Although the rates of growth and backfat deposition are linear in the range of weights to 130 kg (287 lb), these rates are different for different pigs. Thus adjustment factors must consider the individual's rate of growth or backfat deposition.

Since slaughter of heavy hogs reduces the overhead and labor costs for meat processor and producer, it seems likely that the industry will proceed toward production of more rapid growing hogs that are slaughtered at heavier weights. Research results clearly indicate that backfat deposition can be reduced and growth rate improved by selection.
Literature Cited


