GROWTH PATTERNS IN PIGS OF DIFFERENT MATURE BODY SIZE

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Introduction

Davies & Kallweit (1979) suggested that the muscle:bone ratio was an indication of the musculoskeletal maturity of the pig. They used the German Landrace and the Göttingen Miniature breeds as a model, because they mature at very different body sizes. Growth effects due to body size and growth effects due to maturity could therefore be separated effectively. This model was, however, incomplete because it did not include mature animals. Neither could it explain the postnatal increase in the muscle:bone ratio, or the association of this ratio with maturity. This report is therefore an extension of the previous study to include mature animals. It also studies the ash content of the limb bones of these two breeds, to determine if the decreasing proportion of bone in the body during growth can be accounted for by the pattern of mineralisation.

Materials and methods

In addition to the 21 male German Landrace and 12 Göttingen Miniature pigs, castrated before their liveweight exceeded 8 kg, that were previously studied (Davies & Kallweit, 1979), three female pigs of each breed at the upper limit of the previous liveweight range, and six sows of each breed, older than 3 years with liveweights of about 230 kg for the Landrace, and older than 2 years with liveweights of about 56 kg for the Miniature, were killed and dissected as before (Fig. 1). The diet and environment of the mature sows was normal for that of a high producing herd.

Nine bones or bone groups (scapula, humerus, radius and ulna, carpal and metacarpal bones, hip bone, femur, patella, tibia and fibula, and tarsal and metatarsal bones) from the half carcass of each pig were ashed in a muffled furnace until further weight loss was negligible. Bones from two pigs of the earlier study were not available for ashing.

The growth in weight of body components, relative to the growth in body weight, was measured using double logarithmic relationships (Fig. 2). Here, the logarithm of the weight of muscle and bone is plotted against the logarithm of liveweight. Linear equations of the form

$$\text{Log } Y = \log a + b \cdot \log X$$

were calculated by the least squares regression technique. To this end, liveweights at slaughter were chosen to cover the postnatal range of growth by multiplicative increments (Fig. 3). Linear relationships were satisfactory over the growth range studied. No correlation coefficients were lower than 0.997, for the equations reported here. The lines therefore described the "allometric" relationship between X and Y:

$$Y = a \cdot X^b$$

The value of b in this equation is a "growth ratio" (Huxley, 1928), because it represents the multiplicative growth of Y relative to X. Allometric equations are useful for predicting values of X for given values of X, and also for predicting the difference between two such values of Y; such a logarithmic difference is a ratio (Fig. 2).

Because the growth of fat was more variable than either muscle or bone and differed considerably between the two breeds (Davies & Kallweit, 1979), it was necessary to eliminate its effect by comparing the growth of musculoskeletal components with the growth of the fat free carcass, as estimated by total muscle plus bone (Figs. 3 and 4).

Results

The regression equations describing the growth of muscle, bone, limb bone and limb bone ash relative to muscle plus bone in the half carcass are given in Table 1, and shown graphically in Figs. 3 and 4.

For both breeds, muscle grew significantly ($P < 0.001$) faster than total bone or limb bone. Limb bone ash in the Landrace grew at a similar rate to muscle, but in the Miniature was significantly ($P < 0.001$) faster growing than muscle. Limb bone ash was significantly ($P < 0.01$) faster growing in the Miniature than in the Landrace. Otherwise, the breed differences in tissue growth were small and not statistically significant.

Table 2 shows absolute values of tissue weights and their ratios at three different stages of growth; birth, an immature stage at which the Landrace has the same muscle plus bone weight as the mature Miniature and the muscle plus bone weight is one sixth of the mature weight of each breed, and the mature adult. The differences in muscle:bone ratios and in limb bone:limb bone ash ratios between each breed are small compared with the differences between each stage of maturity. The muscle:bone ratio increases, and the limb bone:limb bone ash ratio decreases during maturation. In the Landrace, the maturation changes cancel each other out so that the muscle:limb bone ash ratio declines only very slightly. In the Miniature, the decline is greater, because of the faster bone ash growth for this breed.

None of the ratios are similar between the breeds when compared at the same muscle plus bone weight of 10 kg.

Discussion

Allometric equations adequately describe the growth of muscle, bone and bone ash of the pig, over a period from soon after birth to maturity. By increasing the growth range, the correlation coefficient has been increased to 0.997 and 0.998 for the Landrace and Miniature respectively, from a value of 0.996 for both breeds when mature animals were not included (Davies & Kallweit, 1979). The growth range now represents a 105-fold increase in body weight for the Landrace and a 50-fold increase for the Miniature (Fig. 1). The use of allometry to describe the growth of pig carcass components over any stage within this range can therefore be recommended.

The sexes used in this extended study are mixed. The newborn pigs are entire males, the growing pigs are castrates, and the mature pigs are females. There was, however, no difference discernable in muscle and bone growth between the three castrates at the upper limit of the previous range, and the three females used at the similar weights. There are no reports of comparisons of mature females and mature castrated male pigs, but at a half carcass weight of about 25 kg, the muscle-bone ratio is closely similar for females and castrates (Davies, Pearson & Carr, 1980). It is not expected that the sex difference is sufficient to reduce the value of the equations obtained from this study.

The change in muscle:bone ratio can now be explained by the progressive mineralisation of bone. Growing, immature bone is less mineralised. It is also heavier than mature bone relative to muscle weight. The immature animal must transport a bone weight greater than optimal, until its bone growth ceases.

The recognition of an increase in the muscle:bone ratio postnatally, and its association with musculoskeletal maturity as suggested by this model of dwarfism, is important when animals of large and small body size are compared. Comparisons of such animals at the same liveweight will make the large maturing animal appear to have excessive bone development.

Acknowledgements

This work was begun and extended by the generous assistance of the Alexander von Humboldt-Foundation in Bonn.

References

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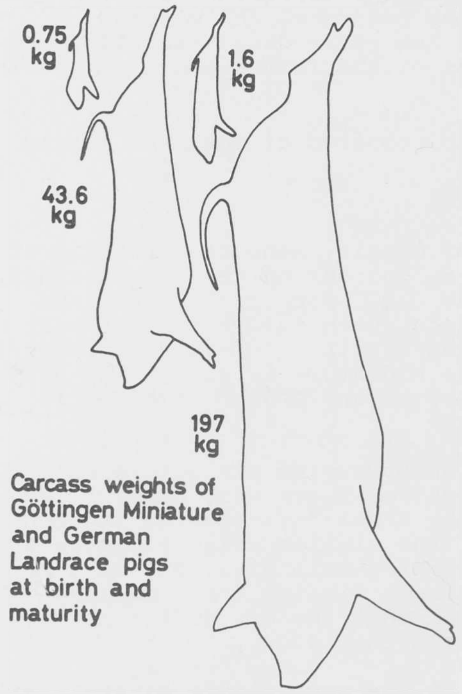

Fig. 1:

The range of carcass sizes used.

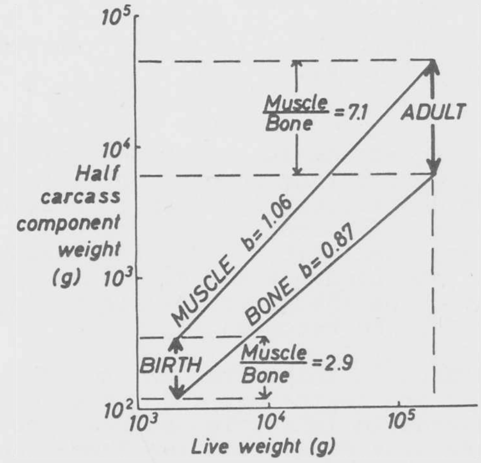

Fig. 2:

The double logarithmic plot of muscle and bone against liveweight, for the half carcasses of 30 German Landrace pigs. The muscle:bone ratio is greater in the adult than at birth. This study is an attempt to explain this increase.

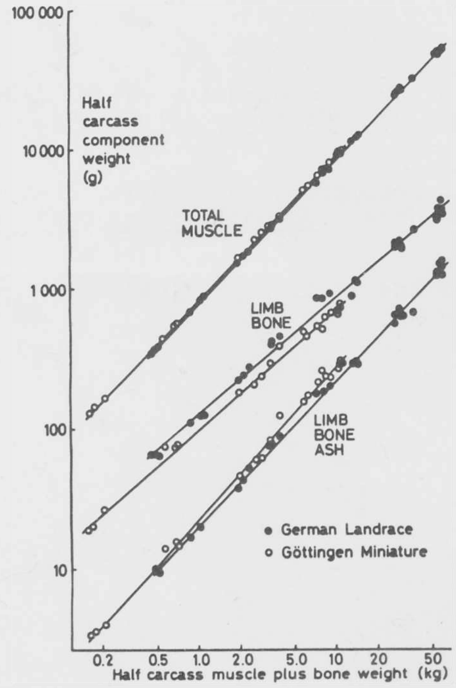

Fig. 3:

Double logarithmic regressions comparing the growth in weight of three musculoskeletal carcass components relative to the muscle plus bone weight of the half carcass, for two breeds of pigs from near birth to maturity.

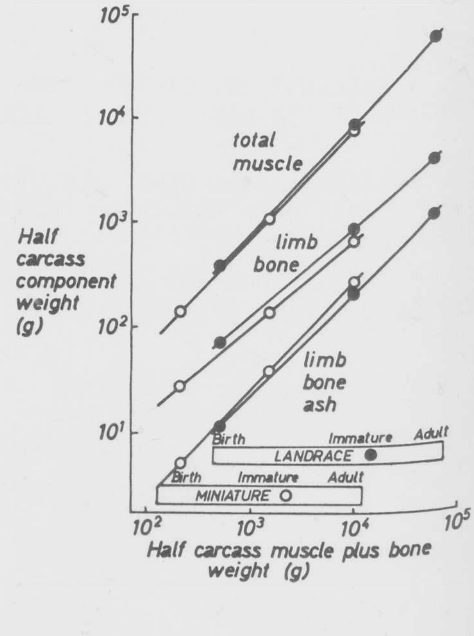

Fig. 4:

The linear regressions of Fig. 3, redrawn to show the stages of maturity chosen to compare values of total muscle, limb bone and limb bone ash and their ratios, between German Landrace and Götting. Miniature pigs, as listed in Table 2.

Table 1: Allometric equations of the form $Y = a \cdot X^b$, comparing the growth of half carcass components Y (in grammes) with total side muscle plus bone X, in German Landrace and Göttingen Miniature pigs.

Component weight Y	Landrace				Miniature				Significance of difference in b between breeds
	n	b	s_b +	log a	n	b	s_b +	log a	
Muscle	30	1.032	0.003	-0.207	21	1.027	0.003	-0.172	NS
Bone	30	0.847	0.011	-0.189	21	0.869	0.014	-0.349	NS
Limb bone	30	0.831	0.013	-0.390	21	0.852	0.015	-0.565	NS
Limb bone ash	28	1.036	0.014	-1.817	21	1.094	0.015	-1.939	$P < 0.01$

+ Standard error of the growth ratio b

Table 2: Weights Y (in grammes) and weight ratios of half carcass components for German Landrace and Göttingen Miniature pigs, calculated from the regression equations given in Table 1, at three stages of maturity, each represented by selected values of muscle plus bone X.

	Birth		Immature		Adult	
	Miniature	Landrace	Miniature	Landrace	Miniature	Landrace
Muscle plus bone (g)	200	500	1670	10000	10000	60000
Muscle	155	379	1370	8340	8630	53000
Limb bone	24.9	71.3	152	859	697	3810
Limb bone ash	3.79	9.53	38.6	212	273	1360
Muscle/ limb bone	6.22	5.32	9.01	9.71	12.4	13.9
Limb bone/ limb bone ash	6.57	7.48	3.94	4.05	2.55	2.80
Muscle/ limb bone ash	40.9	39.8	35.5	39.3	31.6	39.0