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Changes in the Body Composition of Mice Selected for High and Low Eight Week Weight

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Summary. Body composition was studied in three lines of mice, one selected for high (H) and one for low (L) 8 week weight, and one maintained as an unselected control (C). After 25 generations 8 week weights were 41.2g, 30.6g and 20.5g for the H, C and L lines. Mice were sampled from the lines and analysed for fat, protein, ash and water at generations 14 and 25. Apart from fat in the H line, there was little alteration due to selection in the relationships between individual body components and total body weight. In the H line, the contribution of fat to body weight gain was considerably increased. Although leaner than the C and L mice at low body weights, H line mice rapidly became fatter with increasing body weight. Selection appeared to reduce the body weight at which fat was deposited at its maximum rate in the H line. The H and C lines were equally fat at body weights of 29.0g and 21.6g at generations 14 and 25 respectively. Body weights at points of inflection of the growth curves of the H, C and L lines at generation 25 were 18.3g, 14.3g and 12.8g. The implications of these findings for meat species slaughtered at set weights are discussed.

Introduction

Growth rate is an important selection criterion in meat producing animals. Mice have been used extensively to explore the consequences of selection for growth rate on changes in body size and composition (Falconer and King, 1953; Fowler, 1958; Biondini, Sutherland and Haverland, 1968; Lang and Legates, 1969; Meyer and Bradford, 1974). Most of these studies have examined body composition by broadly sampling selection lines between weaning and maturity and do not allow sensitive comparisons to be made in the early stages of growth. Meat animals such as pigs and sheep are often slaughtered at an immature stage of development, usually at a set weight near the onset of sexual maturity, which tends to coincide with the point of inflection of the growth curve (Brody, 1964). This study uses mice to make a more detailed examination of the effect of selection for fast and slow growth rate on body composition, particularly during early life when changes in body size and development are most rapid.

Methods

The mouse lines

A base population was formed by crossing two unrelated laboratory strains, one white and one coloured, and maintained without selection for approximately 5 years. Three lines (H, C and L) were established by sampling within full-sib families of this base population. Selection was for high 8 week weight in the H line, low 8 week weight in the L line and at random in the C line. Mice were single pair mated in individual cages, fed standard mouse cubes and kept at constant 21°C. Litters were weaned at 4 to 5 weeks of age, at which time they were fairly independent of their mothers and suffered no measurable check in growth. The selection lines H and L comprised 17 mated pairs and the C line 30 pairs. Selection was carried out within families (Falconer, 1953), each providing one male and one female to replace its parents which were discarded after littering once. The lines have been maintained in this manner for 26 generations.

Body composition

Results are presented from two samplings of the lines, one after 14 and the other after 25 generations of selection. At generation 14, mice were sampled from the lines weekly over a period of maturing growth from 5 to 12 weeks of age. By taking 3 mice of each sex in a sample, the total number of mice analysed for each line was 48 of each sex. At generation 25, mice were sampled during a phase of immature growth by selecting at random from the families of each line at 3 day intervals between 12 and 36 days of age, a procedure which gave a much more uniform distribution of body weights than the weekly sampling of generation 14. The total number of mice sampled from each line varied with availability but amounted in all to 80 C, 34 H and 66 L mice. Both sexes were equally represented in the samples.

Mice chosen for body composition analysis were killed by overexposure to ether and stored at -24°C until the time of analysis. The frozen mice were homogenized in a blender with a known volume of added water, and the resulting pastes were freeze-dried. The water content of the carcases was calculated from the differences in body weights before and after freeze-drying plus any residual moisture which was determined by heating sub-samples of the freeze-dried material at 105°C for 16 hours. These sub-samples were heated for a further 2 hours at 600°C to measure as content, Fat was measured as the petroleum ether extract after Soxhlet extraction of samples of the freeze-dried material for 16 hours. Protein (N x 6.25) was determined on the defatted samples using the macro-Kjeldahl technique.

Results

Selection response

The extent of divergence of the selection lines from the C line was calculated from the average 8 week weights of the three lines at middle and late stages in selection and is shown in Table 1.

Although both selection lines were symmetrical about the C line at generation 25, response was initially more rapid but attenuated sooner in the L line than in the H line.

Table 1. Mean 8 week body weights of Control (C) and deviations from C of High (H) and Low (L) lines at two stages in selection

	Generations averaged	
	13 and 15	25 and 26
C (mean)	34.24 ± 0.21	30.59 ± 0.30
H (dev.)	6.07 ± 0.42	10.64 ± 0.45
L (dev.)	-9.40 ± 0.37	-10.13 ± 0.48

Maturing growth

Body weight

The average weights of samples of mice taken weekly from the H, C and L lines for body composition analysis at generation 14 are plotted against age in Fig.1. Logarithmic curves were fitted to these points and are drawn in for each line.

H and C line mice grew in parallel between 5 and 12 weeks of age and had evidently not reached mature size by the latter age. Both lines gained approximately 48% of their 12 week weights over this period. The L line mice, however, appeared to have almost reached mature size, having gained only 28% of their final weight during the last 7 weeks of growth.

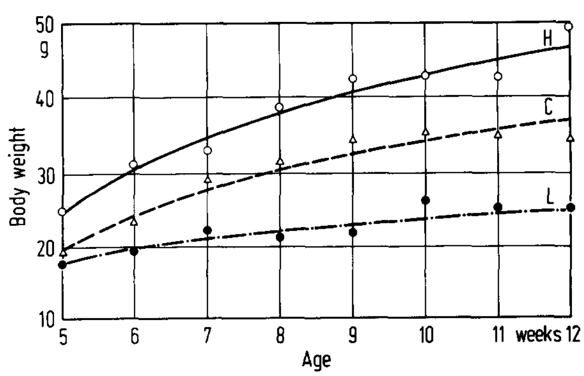

Fig.1. Five to 12 week growth of the High (H), Control (C) and Low (L) lines after 14 generations of selection. Logarithmic curves have been fitted to the average weights of mice sampled for body composition analysis

Body composition

The weight of each body component (Y) fat, protein, ash and water, was related in turn to total body weight (X) by fitting the allometric equation $Y = aX^b$ (Huxley, 1932). These relationships are plotted in Fig.2 over the range of body weights of mice sampled from each of the three lines. Estimates of the parameters are given in Table 2.

As judged by the r values in Table 2, the allometric equation adequately described the relationship between protein, ash, water and total body weight but was less satisfactory for fat, particularly in the C and L lines. As can be seen in Fig.2, the greatest difference between the lines occurred in this latter component. Although the range of overlap of the curves of the three lines was narrow, differences in a values were suggestive of less fat in low body weight mice of the H line than of the C and L lines, but differences in b values indicated a higher contribution of fat to body weight gain in the H line than in the C and L lines. As a result of crossing of their fat curves, the H and C lines had an equal 2.9 g of fat at a body weight of 29.0 g.

Immature growth

Body weight

From weighings of mice at three day intervals in generation 25, growth curves were obtained for the H, C and L lines from birth to 8 weeks. Portions of these curves from 12 to 36 days of age, the period during which mice were analysed for body composition, are plotted in Fig.3.

From average birth weights of 2.0 g, 1.8 g and 1.4 g, the H, C and L lines diverged to 32.7 g, 23.3 g and 18.4 g at 36 days. Maximum growth occurred in all lines between weighings on the 24th and 27th day of age. Average gains per mouse during this 3 day period were 4.8 g, 3.3 g and 2.4 g for the H, C and L lines respectively. Points of inflection of the growth curves estimated from 25.5 day weights taken from Fig.3 were 18.3 g, 14.3 g and 12.8 g.

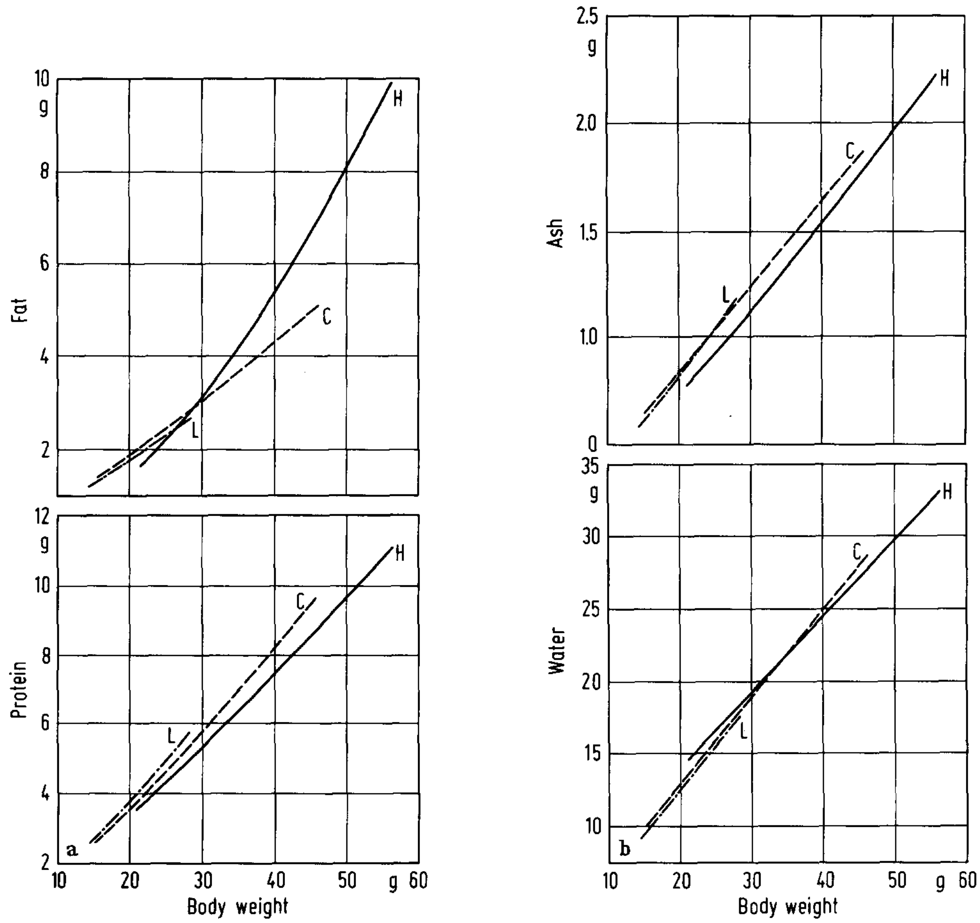

Fig.2. Allometric equations ($Y = aX^b$) relating body components (Y) and total body weight (X) of mice analysed at generation 14

Table 2. Parameters of relationship $Y = aX^b$ between the weight of body components (Y) and total body weight (X) of mice analysed at generation 14

	Fat			Protein			Ash			Water		
Line	a	b	r*	a	b	r	a	b	r	a	b	r
H	0.01	1.82 ± 0.16	0.82	0.12	1.12 ± 0.04	0.95	0.03	1.06 ± 0.06	0.91	0.82	0.82 ± 0.03	0.95
C	0.06	1.16 ± 0.17	0.65	0.11	1.17 ± 0.04	0.96	0.05	0.96 ± 0.08	0.84	0.83	0.92 ± 0.02	0.98
L	0.07	1.11 ± 0.18	0.66	0.10	1.22 ± 0.07	0.93	0.04	0.98 ± 0.10	0.82	0.83	0.92 ± 0.03	0.98

r* correlation co-efficient

Table 3. Parameters of relationship $Y = aX^b$ between the weight of body components (Y) and total body weight (X) of mice analysed at generation 25

	Fat			Protein			Ash			Water		
Line	a	b	r*	a	b	r	a	b	r	a	b	r
H	0.01	1.60 ± 0.03	0.93	0.18	0.97 ± 0.03	0.99	0.02	1.10 ± 0.04	0.98	0.80	0.96 ± 0.01	1.00
C	0.05	1.16 ± 0.08	0.84	0.20	0.88 ± 0.03	0.97	0.03	1.03 ± 0.04	0.95	0.78	1.00 ± 0.02	0.98
L	0.03	1.28 ± 0.09	0.87	0.19	0.97 ± 0.02	0.98	0.02	1.16 ± 0.03	0.97	0.71	0.96 ± 0.01	1.00

r* correlation co-efficient

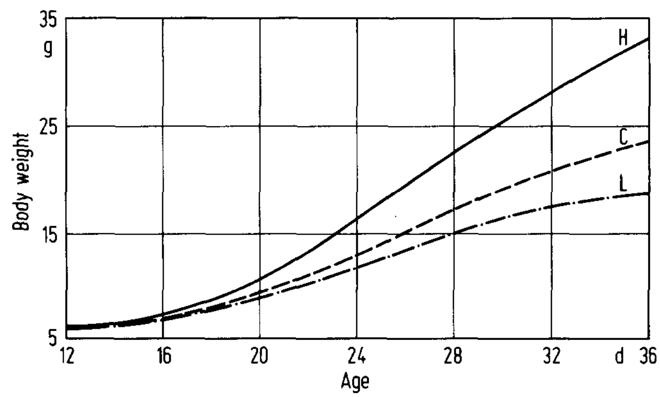

Fig.3. Curves of mouse growth from 12 to 36 days of age, the period in which they were sampled for composition analysis at generation 25

Body composition

Curves fitted to weights of the four body components against total body weight are drawn for the three lines in Fig.4. Parameter estimates are given in Table 3.

Compared with the generation 14 samplings, the curves share a much wider range of body weights and their r values are higher. Again there was a good fit of the allometric relationship for protein, ash and water but a less satisfactory one for fat, particularly in the C and L lines. The b values differed significantly between lines for all components except water. Showing much more clearly than in the early analysis is the leanness of the H line relative to the C and L lines during this phase of early growth. This resulted from an initial delay, followed by a rapid rise, in fat deposition relative to body weight. The fat curves of the H and C lines crossed at a fat weight of 1.6 g and a body weight of 21.6 g. These were 55% of the fat weight and 75% of the body weight at a similar crossover point for the fat curves of the H and C lines in generation 14.

Discussion

The two phases of this study, maturing growth at generation 14 and immature growth at generation 25, throw different lights on changes in body weight and composition with selection for growth rate. The changes in the shapes of the growth curves of the H and L lines resemble those of other studies reviewed by Roberts (1965). In agreement with Eisen, Lang and Legates (1969), selection for growth rate has increased body weight at the point of inflection of growth in the H line and decreased it in the L line but has not altered the age at that point.

Reid (1968) concluded, from a review of changes in body composition accompanying the growth of animals, that the relationship between the weights of each chemical component of the body and body weight itself is closely fitted by the allometric equation. This relationship is independent of age or previous level of energy input, but differs somewhat between breeds. Thus the allometric equation was chosen to compare the body compositions of the three genetically different selection lines of this study. Such a method of comparison, on a body weight rather than an age scale, has more relevance to such domestic species as pigs which are slaughtered at a set liveweight rather than a set age. At both the generation 14 and 25 samplings, fat was the only body component for which there was a marked difference between the lines. The sensitivity of this component to selection for body weight in mice has been reported elsewhere. Clarke (1969), Fowler (1958) and McCarthy (1974) demonstrated changes in the pattern of fat deposition in lines selected for growth rate which were very similar to those found during maturing growth in this study. All these analyses lacked detailed information at lower body weights during the period of immature growth. Also the range of body weights, common to all lines and within which valid comparisons between lines could be made, was rather narrow. Nevertheless they all showed that selection for rapid growth resulted in a marked rise in the contribution of fat to body weight gain. They also suggested an initial delay in this rise so that immature mice actually became leaner with selection. This was confirmed by the generation 25 sampling of the H, C and L lines, the points of inflection of whose growth curves all fell in the middle of the sampling range.

A comparison of fat curves in generations 14 and 25 (Figs. 2 and 4) suggests that the intervening generations of selection for rapid growth reduced the body weight at which fat was deposited at its maximum rate in the H line. This change in the crossing point of the fat curves in the H and C lines has implications for growth rate selection in such domestic animals as bacon pigs. These are slaughtered in the vicinity of the point of inflection of their growth curves and high growth rate and low carcase fat at this point are im-

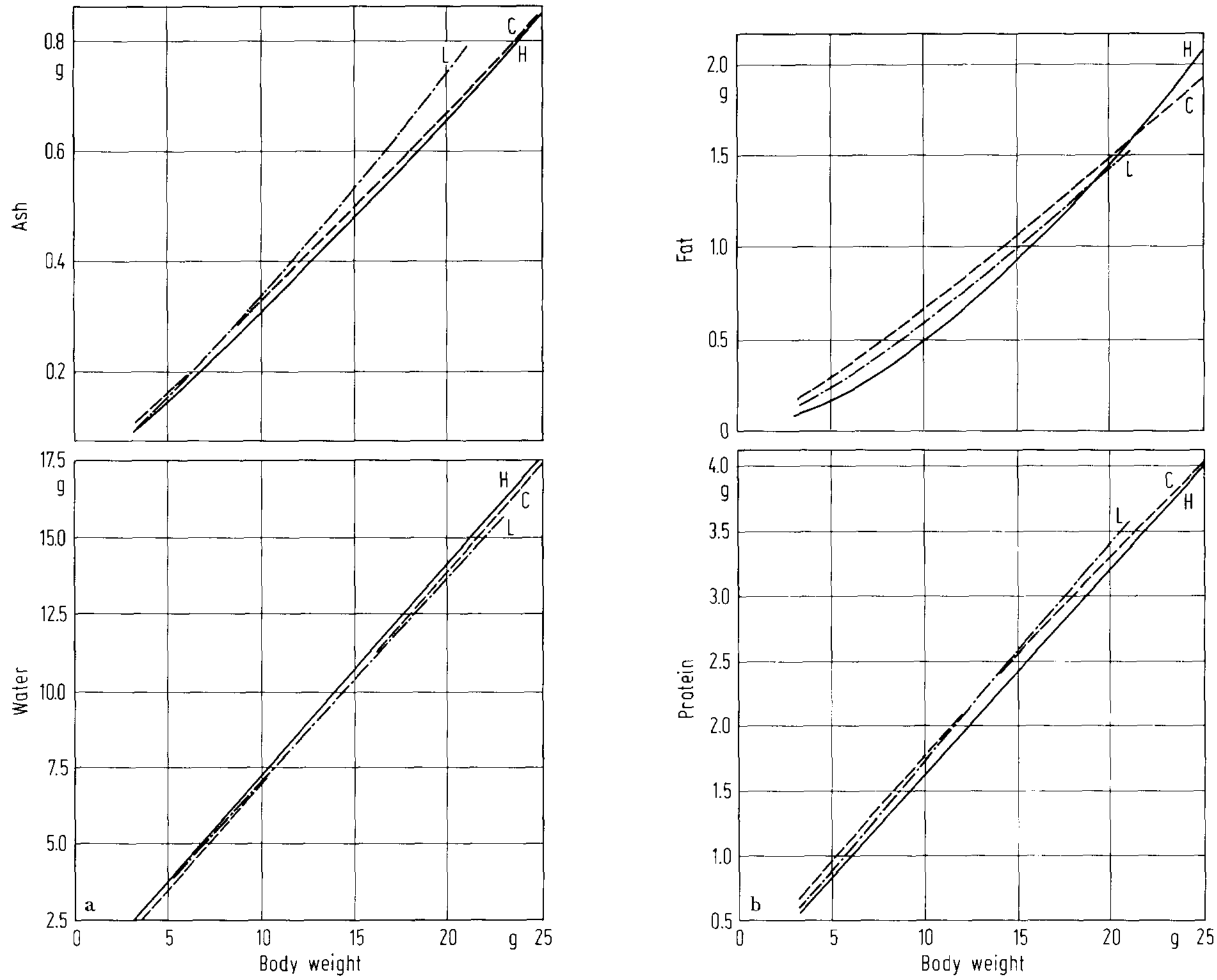

Fig.4. Relationships between body components and total body weight of mice analysed at generation 25

portant selection objectives. Transposing to the mouse lines, an equivalent slaughter weight can be assumed to be fixed at 14.3g, the point of inflection of growth in the C line as estimated at generation 25. Extrapolation of the generation 14 fat curves in Fig.2 to this weight suggests that both selection objectives of increased growth rate and reduced fat had already been achieved in the H line. An additional 11 generations of selection increased growth rate further but led to an undesirable increase in fat. The crossing of the fat curves of the H and C lines also suggests that selection has exposed an underlying genetic correlation between growth rate and fatness in the base population which passes from negative through zero to positive with increasing age and body weight. If a similar situation exists in pigs, then the point of zero correlation is probably close to bacon weight.

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