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Feed Efficiency and Body Composition of Selected and Unselected Mice*

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Summary. An examination was carried out of the feed intake, feed efficiency and body composition of selected and unselected mice. It was demonstrated that selected mice utilised food more economically, and, in total, produced more protein than the control animals. However, selection had a negative influence on the percentage content of protein and ash. Also, selection caused greater adiposity of selected females and a greater water content in the bodies of selected males (in %).

Key words: Mice - Feed Efficiency - Body Composition - Protein Content - Selection

Introduction

In the breeding of farm animals the daily weight gains are considered one of the more important selection criteria. The quantity of food consumed by the animals per unit of gain and the carcass components giving rise to the increase of body weight are also significant problems. At present, main attention is paid to the maximum accumulation of protein in the muscle tissue. This problem has been analysed by Kielanowski (1972) and many others. However, because it is easiest to examine the influence of selection of feed efficiency and on the accumulation of various components in the body on laboratory animals, many investigations have been devoted to these questions using mice or rats as experimental material.

McPhee and Neill (1976) analysed the body composition of mice selected for large and small weights at the age of 8 weeks - and of unselected mice - and demonstrated that at low body weights the mice selected for large weights contained the least fat. The adiposity of mice from the same line increased quickly with increasing body weight. Moreover, these authors recorded that the correlation coefficients between the body weight and content of fat, protein, water and ash were high in the lines examined. In turn Timon et al. (1970) demonstrated a better feed conversion in mice selected for large weight gains than in those unselected. They also found a percentage increase of fat and a lower percentage of water in the tissues of selected animals as compared with those unselected. Biondini et al. (1968) found that the increase in the fat percentage content in mice selected for greater weight gains amounted to 73 %, while the protein content simultaneously decreased by about 16 % (compared with the control mice).

Van der Wal et al. (1976) investigated the accumulation of fat and protein in two mice lines, maintained on different nutrition levels and selected for weight gains and litter size. They examined the body composition of mice of various ages and demonstrated considerable differences between the lines, principally in relation to the maintenance system. Dawson et al. (1972), analysing the body composition of mice selected according to various selection indexes, also demonstrated significant differences in the chemical composition of the animals examined.

As regards food intake, Roberts (1973) demonstrated that mice selected for large body weights at the age of 6 weeks consume about 20 % more food than did the controls, while mice selected for small body weights took 20 % less food than the control ones. Similar results were obtained by Brown and Frahm (1975). These authors ascertained that mice selected for increased body weights and weight gains

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consumed about 17.4 % more food, but simultaneously their feed efficiency was as much as 21.6 % better compared with the control animals.

Notter et al. (1976) estimated the heritability (regression of offspring on midparent) of the rate of lean gain as 0.20 ± 0.12 and of the efficiency of protein gain as 0.24 ± 0.8. Sutherland et al. (1970) recorded the realised heritability of growth rate as 0.23 ± 0.020, of feed efficiency 0.17 ± 0.042, and of feed intake 0.20 ± 0.057.

Jara-Almonte and White (1974) ascertained that the heritability of feed intake ranged between 0.25 and 0.31 and of feed conversion between 0.10 and 0.21. According to these authors feed intake was correlated with the weight gains and between the 21st and 42nd day of life it amounted to 0.52; between the 42nd and 56th day it was 0.71, and between the 21st and 56th day 0.75. The respective genetical correlations amounted to 0.91, 0.98 and 0.85.

Gall et al. (1967) stated that the protein metabolic activity demonstrated a positive genetical correlation with the body weight, carcass weight and with content of nitrogen in the carcass of 28 day old mice. Kownacki et al. (1975), examining the basal metabolism of selected and unselected mice maintained on various nutritional levels, ascertained a negative correlation between the growth rate of young mice and their basal metabolism at the age of 5 months. The differences in basal metabolism between the selected and unselected mice were significant statistically. Thus the present investigations were aimed at developing the experiments conducted previously. An analysis was carried out of the total feed intake and feed intake per 1 gram of weight gain by mice selected for increased weight gains, aged 3 to 6 weeks, and by unselected ones. A comparison was also made of the body composition of animals from those lines.

Materials and Methods

The mice used for the experiment (Kownacki and Zuk 1977) were subjected to mass selection for weight gains between the 3rd and 6th week of age in populations of different sizes over 16 generations. The populations were composed of the following number of animals: 10(5♂ + 5♀), 20(10♂ + 10♀), 50(25♂ + 25♀), 100(50♂ + 50♀), 150(75♂ + 75♀) and 200(100♂ + 100♀). Each population corresponded with an identical unselected control population. The experiment was conducted in 3 replications.

During the selection experiment mating between full-sibs was avoided in order to diminish inbreeding. After birth, the litters were reduced to 8 animals in order to equalize the litter sizes. The animals were placed in a mouse room lit for 12 hours per day, at a temperature of about 20-22°C and humidity about 60 %. They were fed on a standard pelleted food.

The animals from the 16th generation were used for crossing between replicates both in selected and control populations, according to the following method:

I crossing - between replicates A, B and C

A♂ × B♀
C♂ × A♀
B♂ × C♀

II crossing

AB♀ × C♂
AC♀ × B♂
BC♀ × A♂

Thus, animals were produced with the accumulated selection responses and free from inbreeding. For these investigations only mice from the largest population were used - 200(100♂ + 100♀) - in which the selection response was the largest. From this population, from each replicate and from each litter, one female and one male were chosen at random for nutritional investigations and the analysis of body composition.

These investigations were aimed at examining to what degree the selection for weight gains influenced the feed efficiency and body composition.

The material was analysed separately for males and females both in the selected and unselected lines. A record was made of the quantity of food consumed between the 3rd and 6th week of life and the quantity of food consumed per 1 g of weight gain was calculated. The analysis of body composition covered the determination of water, protein, fat and ash content.

The quantity of food consumed was determined for each animal separately, as the mice were kept in specially constructed, individual cages. For one chemical analysis three animals of the same sex (1 from each litter) were used. After 24 hours of fasting (free access to water) the mice were killed with chloroform and autoclaved in hermetic glass containers (3 animals in each container). In those same containers the animals were homogenised in order to obtain uniform samples. The material thus obtained was used for the following analyses (according to commonly accepted methods):

1. Water content - gravimetrically (dried at 105°C)
2. Protein content (N × 6.25) - Kjeldahl's method
3. Fat content - Soxhlet's method
4. Ash content - gravimetrically (in a muffle furnace).

For the statistical calculation an analysis of variance was used, taking into consideration the variation between populations (selected and control), between replicates and within replicates. As a smaller number of animals was used (3 mice for 1 analysis) for the analysis of the chemical body composition, the variation between replicates was omitted. The comparison of individual groups of animals (in the case of chemical analysis) was performed by way of Duncan's test.

Results

Response to selection

As a result of selection conducted for 16 generations the animals decidedly differed from the unselected controls. Differences occurred in weight gains between the 3rd and 6th week of age, which was also reflected in the body weights of 6 weeks old mice (Table 1). The differences between the selected and unselected animals were highly significant, both in the 16th generation and after the reciprocal crossing of three replicates. This reciprocal crossing was aimed at comparing the selected and unselected animals when free of inbreeding.

Although the coefficient of inbreeding was low in the 16th generation (0.74 % in the selected and 0.50 % in the control population) it is worth emphasising that the reciprocal crossing of replicates did not cause an increase in body weights and weight gains of mice, but on the contrary - a decrease. Slightly similar results were obtained by Rutledge et al. (1974). However, Falconer (1964) states that 1 % of inbreeding causes a depression in the body weight of 6-week-old mice reaching 0.26 %.

The selection results obtained in the whole population, after reciprocal crossing of the lines (Table 1), differed slightly from the results obtained in the groups of animals used for nutritional investigations (Table 2). However, this is justified as the animals used for the nutritional experiments were kept in individual cages between the 3rd and 6th week of age, in order to control the quantity of food consumed.

Table 1. Mean body weights and weight gains of mice in the whole population in grams (before and after reciprocal crossing)

Animals	Type of line	Sex	n	Weight at 6 weeks old $\bar{x} \pm$ S.E.	Postweaning weight gain $\bar{x} \pm$ S.E.
From 16th generation	Selected	♂	597	29.97 ± 0.21	19.28 ± 0.19
		♀	598	25.81 ± 0.20	13.37 ± 0.22
	Unselected	♂	554	22.27 ± 0.26	15.40 ± 0.22
		♀	543	19.36 ± 0.25	10.62 ± 0.21
Animals obtained by reciprocal crossing of replicates	Selected	♂	739	28.93 ± 0.36	18.60 ± 0.27
		♀	670	24.42 ± 0.28	14.49 ± 0.18
	Unselected	♂	655	22.79 ± 0.31	12.81 ± 0.19
		♀	659	19.26 ± 0.22	9.56 ± 0.17

n = number
$\bar{x}$ = mean
S.E. = standard error

Table 2. Weight gains, feed intake and feed efficiency obtained for mice used for the nutritional investigations (in grams)

Type of selection	Sex	n	Postweaning weight gains $\bar{x} \pm$ S.E.	Feed intake between the 3 and 6 week $\bar{x} \pm$ S.E.	Feed intake per 1 g of weight gain between 3 and 6 week $\bar{x} \pm$ S.E.
Selected	♂	134	16.29 ± 0.20	99.52 ± 0.92	6.23 ± 0.09
	♀	136	13.90 ± 0.18	97.21 ± 0.96	7.14 ± 0.14
Unselected	♂	159	11.98 ± 0.21	93.57 ± 0.87	8.20 ± 0.18
	♀	161	9.38 ± 0.18	89.80 ± 0.78	10.60 ± 0.28

n = number
$\bar{x}$ = mean
S.E. = standard error

Table 3. Summary of the analysis of variance for weight gain, feed intake and feed efficiency

Source	Degrees of freedom ♂	Degrees of freedom ♀	Mean square: Postweaning weight gain ♂	Postweaning weight gain ♀	Total feed intake ♂	Total feed intake ♀	Feed intake per 1 g of gain ♂	Feed intake per 1 g of gain ♀
Total	292	296						
Between populations	1	1	1349.09**	1509.97**	2571.08**	4051.09**	285.81**	752.39**
Between replicates	4	4	22.75**	18.69**	841.03**	776.71**	24.59**	43.89**
Within replicates	287	191	5.95	4.79	106.96	101.10	2.92	7.58

* Significant at level P = 0.05
** Significant at level P = 0.01

Feed intake by mice between the 3rd and 6th week of age

During the period investigated the selected mice assumed more food than the control ones (Table 2). The differences were highly significant ($P < 0.01$) in the groups of both females and males (Table 3). However, one must emphasise also that the body weights and weight gains of selected mice were considerably higher than those of the control animals. The crossing of replicates also had a significant influence ($P < 0.01$) on the feed intake between replicates in both the groups of males and females (Table 3).

Feed intake per 1 g of weight gain between the 3rd and 6th week of age

Highly significant differences ($P < 0.01$) were ascertained in the food intake per 1 g of weight gain between the selected and control mice. The selected mice used considerably less food (males by 1.97 g - 24.02 % and females by 3.46 g - 32.64 % per 1 g of weight gain) than the control ones (Table 2). The crossing of replicates had significant influence on the differences in the feed efficiency between replicates (Table 3).

Body composition of the animals investigated

It was clear from the investigations conducted that selection for increased weight gains between the 3rd and 6th week of age also caused changes in the body composition of the animals selected (Table 4). In particulars highly significant differences ($P < 0.01$) occurred in the percentage content of protein and ash in favour of the unselected animals. Significant differences in fat content were observed only in the group of females, which after selection were char-

Table 4. Chemical analysis of the body composition of mice (in %)

Line	Group	Sex	Number of animals	Number of analyses	Water	Fat	Protein	Ash
Selected	1	♂	117	39	70.36 ± 0.15	4.59 ± 0.17	21.18 ± 0.11	3.58 ± 0.04
	2	♀	120	40	70.13 ± 0.21	5.66 ± 0.21	20.04 ± 0.08	3.80 ± 0.04
Unselected	3	♂	147	59	69.52 ± 0.14	4.69 ± 0.16	21.66 ± 0.09	3.82 ± 0.03
	4	♀	150	50	69.70 ± 0.17	4.99 ± 0.16	20.85 ± 0.12	4.10 ± 0.03
Significance of differences between groups					1 and 3**	1 and 2** 2 and 4*	1 and 2** 1 and 3** 2 and 4** 3 and 4**	1 and 2** 1 and 3** 2 and 4** 3 and 4**

* Significant at level P = 0.05
** Significant at level P = 0.01

acterised by a higher percentage content of this component compared with the control group. Also, for the percentage content of water in the body, the selected males surpassed ($P < 0.01$) the unselected males. In the group of females no significant differences in water content were found between the selected and unselected animals.

Highly significant differences ($P < 0.01$) occurred between the males and females in percentage content of protein, ash and fat (fat only in the case of selected animals). In the groups of both selected and control animals the females demonstrated a higher ash content while the males showed a higher protein content. Only the selected females were characterised by a higher fat content than the males.

On the basis of the chemical analyses it seems that the selection conducted had a negative influence on the quality of the animals' body composition. The results obtained approach those recorded by Biondini et al. (1968), Timon et al. (1970), Dawson et al. (1972) and others.

Recapitulating, one can state that selection had a positive effect from the breeders' point of view. As a result of selection the weight gains increased significantly, the animals utilised their food more economically and, in absolute terms, produced considerably more protein than the control ones. At the age of 6 weeks one selected male produced on average 5.68 g of protein and one selected female 4.83 g of protein, while the control males produced only 5.16 g and control females 4.16 g of protein.

Discussion

Because selected mice have, as a rule, a higher degree of inbreeding than the controls, unselected ones, a reciprocal crossing was carried out of the three replicates, both within the selected and control mice. Although in the present experiment inbreeding was not very intensive (0.74 % in selected and 0.50 % in control animals) it could influence the experimental results. Thus the reciprocal crossing between replicates was conducted in such a way as to obtain animals with the accumulated responses and completely free of inbreeding, and differing only in one factor - selection.

From the investigations conducted it seems that selection had a decisive positive influence not only on the size of weight gains between the 3rd and 6th week of age but also on feed efficiency. The selected mice used highly significantly ($P < 0.01$) less food per 1 g of weight gain than the control animals. These results correspond with those obtained by Timon et al. (1970), Brown and Frahm (1975) and other authors.

From the chemical analyses of the body composition of selected and unselected mice it is clear that selected mice have a smaller percentage content of protein and ash, while selected females also have more fat. Moreover, the selected males are characterised by a greater percentage content of water in the body than the unselected ones.

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