

## GENETIC ASPECTS OF GROWTH, FEED EFFICIENCY AND EFFECTS OF SELECTION ON THESE TRAITS IN MICE: A REVIEW

Orhan ÇETİN \*

Farelerde Büyüme ve Yemden Yararlanmanın Genetik Yönü ve Seleksiyonun Bu Karakterler Üzerine Etkisi (Derleme).

**Özet:** Bu derlemede farelerde büyümenin genetik yönü, farklı yemleme rejimleri altında yapılan uzun ve kısa süreli seleksiyon çalışmalarının canlı ağırlık kazancı, yemden yararlanma ve yem tüketimi üzerine etkileri incelendi. Hatlar arası ve hatlar içi varyasyonlardan canlı ağırlık ve büyüme hızı için hesaplanan genetik parametreler; aslında canlı ağırlık, canlı ağırlık kazancı, yem tüketimi ve yemden yararlanma yönünde yapılan seleksiyonlardan indirek olarak hesaplanmıştır. Yemden yararlanma ve diğer karakterler arası ilişkiler geniş olarak özetlenmiştir.

Üzerinde seleksiyon uygulanan karakterler kısa süreli seleksiyonda, uzun süreli seleksiyona göre kalitatif olarak farklılık gösterirler. Kısa süreli seleksiyonda seleksiyonun etkisi karakterler arasındaki genetik korrelasyonlara bağlı iken, uzun süreli seleksiyonda ise genotipik ve fenotipik korrelasyonlara bağlı olmayıp tabii ve direk seleksiyon etkisi altındadır.

**Anahtar kelimeler:** Fare, seleksiyon, büyüme, yemden yararlanma, yem tüketimi.

**Summary:** A review is presented of the genetic of growth, effects of long and short-term selection experiment under different feeding regimes on weight gain, feed efficiency and food consumption in mice. The genetic parameters considered are; nature and extend of within and between line genetic variation for body weight and growth rate; correlated response to selection for body weight, weight gain, feed intake and feed efficiency. The relationships of feed efficiency with other traits is reviewed at length.

The response of characters to selection in the short-term differ qualitatively from those in the long term. In the short term, the responses depend on genetic correlations between characters, but in the long-term they are only determined by fitness function of natural and directional selection, independent of genetic and phenotypic correlations.

**Key words:** Mice, selection, growth, feed efficiency, food consumption.

### INTRODUCTION

The purpose of selection in the animal production has been to increase the efficiency of their input and output values. The goal to achieve that purpose is an animal which grows fast with a minimum amount of feed to be converted efficiently into meat and from that perspective, more studies have been done the change to rate of growth and body composition.

Extensive use of the laboratory mouse as a

mammalian model has made it a unique material in studies of growth. In mouse, selection is performed for increased growth rate which is achieved by selection for body weight gain. Growth is a biologically complex character expresses a coordinated development of various parts and organs of body, and so it is a composite trait. It is the last product of many different physiological processes and is controlled by many genes (27). Selection for growth rate or body weight gain also give rise to some major correlated responses which are increased in feed intake, feed efficiency and changes in body composition.

The nature of the interrelationships has not been clearly understood for some of the traits involved in growth processes. The size of the experiments, the lack of replication plus the fact that relationships change with age environmental conditions have been major obstacles.

The responses of characters to selection in the short-term differ qualitatively from those in the long-term. In the short-term, the responses depend on genetic correlations between characters but in the long-term they are only determined by the fitness function of natural and directional selection, independent of genetic and phenotypic correlations (57).

### SELECTION FOR BODY WEIGHT

Since body weight is easy to measure, it has been a preferable parameter to estimate overall growth and responds to selection readily. Selection research with laboratory mice are cheaper, easier and require a short generation period therefore it has been most wellcome as a model for livestock production. Body weight is mainly quantitative in nature (10). Roberts (37), concluded that variation in the body weight of the mouse mainly was effected by the additive genetic effects. Additive expresses the resemblance between relatives and important for heritability of traits. It has major effects in response to selection (13). Additive genetic variance for body weight gain at a later period may be limited (3, 51,55).

Realized heritability estimates of body weight

in mouse range from 0.22 to 0.42 (1, 2, 10, 12, 30, 32, 33). In addition, a lower estimate of 0.13 was reported by Cheung and Parker (7), and a higher estimate of 0.55 by Eisen (8).

High genetic correlation between body weight and at successive ages have been reported by Hull (22), Fraham and Brown (17), and Baker et al. (2).

According to Roberts (38), mice selected for increased body weight at a given body weight at a given post-weaning age respond constantly to selection for about 20 generations with a fairly linear response and then the response starts to decline. He added that response to selection for body weight in mice does not continue indefinitely, but does indeed reach a definite limit. There is almost no additional increases in body size after 35 generations of selection reported by Wilson et al. (56).

#### **SELECTION FOR GROWTH RATE**

The rate of body weight gain is defined as growth rate expressed in terms of increase in body weight over a specific period of time.

Selection for growth rate has been found to have high heritability which makes selection for this trait highly effective in mice (4, 11, 19, 25, 36, 46, 55).

Realized heritability estimates of growth rate are lower when we compare with the estimates for body weight. Reported some estimates vary from 0.18 to 0.38 (2, 4, 11, 19, 25, 32, 34, 36, 55). Urrutia and Hayes (51), reported realized heritabilities outside of this range which were higher for the ad libitum line in the early period and restricted line in the late period. They suggested that their estimates were higher but could not be count as a significant, due to their larger standard errors. Timon and Eisen (49), McCarthy and Baker (29) showed that growth rate does not have a proportional impact all ages while body weight does. There is a very high correlation between selection for growth rate and body weight at the end of the selection period, which are ranged between 0.1 and 0.75 (1, 2, 12, 19, 42). However, genetic correlations between growth rate and body weight at the beginning of the selection period are low, which are ranged from 0.20 to 0.47 (2, 17, 21, 54, 55).

In a number of reports, selection for body weight or growth rate has been shown to change in feed consumption, feed efficiency and body composition (5, 9, 16, 31, 46, 50). However, some researchers have indicated little change in body composition (6, 15). Finally Roberts (40), concluded that "Selection for increased body weight in laboratory animals usually, though not always, leads to increase in food intake, gross efficiency and fat deposition, while

some aspects of fertility are usually impaired".

#### **CORRELATED RESPONSE TO SELECTION FOR WEIGHT GAIN AND FEED CONSUMPTION**

Selection for feed consumption can be reached by selection for increased body weight, effected feed consumption largely (5, 16, 23, 24, 31, 34, 46, 50).

Feed consumption increases up to at about 80% of mature weight in mice. Roberts (41) and Taylor (48), suggested that mean voluntary food intake can not be determined at a given age or weight since it depends on the nutritional value of the diet. Since mice drank glucose solution reduced the solid food intake, drinking glucose solution instead of water kept energy intake constant (41). Thus, Roberts (41), concluded that appetite was mediated by some satiety mechanisms. Large mice have bigger body size therefore must intake more food, which obtain necessary energy requirements to them.

Direct selection for feed consumption has been limited and was less effective in changing growth rate than its indirect selection. The reported heritability of feed consumption was 0.20 (46).

Sharp et al. (43) done replicated selection for feed intake. Realized heritability of that experiment was 0.15. They also reported heritability estimates of decreased feed consumption were some magnitude. And line had lower body weights and lower gross efficiency as to be expected. Since mice selected for large size have increases in both food intake and efficiency, and small mice have decreases in both at the same age or same weight base (41).

Most of the experiments were done as a correlated response to selection for feed efficiency. Sutherland et al. (46) found an increase in feed consumption line selected for increased feed efficiency. Gunset et al. (18) found decreased consumption per unit of body weight in which the line selected for increased efficiency. Yüksel et al. (54) reported decreased consumption in the line selected between 3 and 5 weeks of age and increased consumption in the line selected between 5 and 7 weeks of age. Yüksel's (53) conclusion: "Selection for efficiency in mice may affect feed consumption positively, negatively, or not at all" is still valid.

In mice, selected 21 day of age weight gain and weight gain between 21 and 42 day of age, daily feed consumption increased by 17.4 % and 26.9 %, respectively (5). Roberts (39), showed that mice selected for larger body weight at 6 weeks of age consumed about 20 % more food than their controls. Hayes and McCarthy (20), conclude that selection for increased body weight has a positive correlated

response in feed consumption which may vary at different ages. Urrutia and Hayes (51) found positive correlated response in feed consumption in the ad libitum lines in the early period and negative response in the late period while restricted line had a negative response in both periods of selection.

Consumption increases regularly up to 80 % of mature body weight (41). Stephenson and Malik (45), reported that maintenance requirements are increased respectively with increased body size. In review articles, Malik (27), has pointed out that large differences in feed intake and feed efficiency are observed when animals are fed ad libitum which may arise from required energy for either maintenance or tissue growth. The maintenance requirement increases regularly with the increase in body size during the active growth period. In addition, energy requirement for growth itself varies with the growth rate and with the composition of the tissue formed. Therefore corresponding the declining rate of tissue deposition, the amount of energy required for tissue growth decreases with maturation of the age (16, 21, 44, 45). Maintenance is expected to play a greater role in the increased efficiency of selected lines (28). Thus, selection for increased growth rate at later age would be expected to have a less impact on consumption.

#### FEED EFFICIENCY

Efficiency is not a directly measurable trait. First, direct measurements of growth and feed consumption are done and efficiency is then defined as the ratio of gain/ feed or its reciprocal. It can also be measured age to age, or weight to weight or age to weight. Measurement of efficiency on a weight to weight or age to weight bases favors in faster growing animals (35). The measurement of feed/ gain is usually referred to as the food conversion ratio. The most used estimate is gross efficiency, that is feed efficiency for growth refers to the weight ratio of body weight gain to feed consumed or its inverse. Timon and Eisen (50) suggested that since the coefficient of variation of feed/ gain was considerably larger than that for gain/ feed, gain/ feed would be the preferred measure of efficiency, in the case of comparisons over a constant age interval.

Feed efficiency depends on the inter- relationship between feed intake, growth and composition of the body tissue and depends on metabolic process. Therefore it is effected some factors such as age, season, sex, behaviour, activity, temperature, humidity and possibly some other factors.

When it was compared with the other species, mice have poor feed efficiency, because of the high energy requirements for thermoregulation associated with the large surface area to weight ratio. Gross

efficiency increases during the early period of growth and than decreases relatively with age (47, 50).

A review papers by Malik (27), indicated that there is no reason for direct selection for increased feed efficiency, since it appears as a result of selection for weight gain without the expense of food recording. Since then reports of direct selection for increased feed efficiency are very limited number. Realized heritability estimate of this trait has been as reported 0.13 and 0.40 by Yüksel et al. (54) and Sutherland et al. (47), respectively. Gunset et al. (18), have reported higher estimates of heritability of 0.56 and 0.73 for feed efficiency. These later estimates are not compatible with the previous ones since they were measured on different bases.

Sutherland et al. (46), selected the mice lines for both efficiency and weight gain. They found the line selected for efficiency was more efficient than other line. The correlated response in weight gain was greater than the direct response in the line selected for gain. However, Yüksel et al. (54) did not agree with above results. They found average realized heritability estimate of 0.13, and concluded that selection for veight gain would be more effective for increasing feed efficiency than the direct selection for efficiency.

Feed efficiency has been accepted as a correlated response to selection for increased growth. Several researchers have been reported that there is a positive correlation between increased growth and efficiency (5, 16, 24, 31, 46, 50).

Mice selected for large body size consume more food and have relatively greater amounts of energy for increasing body tissue which is either protein or fat (28, 40, 44, 45). Generally, mice having lower maintenance requirements have more energy available for growth. Activity is a behavioral difference, larger mice being less active than smaller and its control (40). Larger mice also have increased nesting behavior (26). Therefore larger mice have superiority conservation of energy. But body temperature was not different between selected lines and control lines (26, 45).

#### SELECTION UNDER RESTRICTED FEEDING REGIME

Mice selected for increased body weight and growth rate under restricted feeding regime grow faster than the control mice as a result of lower maintenance energy requirements (21, 44). However, McCarthy (28) and Roberts (41) suggested that this may be dependent on relatively lower maintenance cost of thermoregulation due to loses heat from their warm bodies to colder environment.

Roberts (41) reported that efficiency declines as a remarkably linear function of body weight.

Considering ages, the efficiency differs in the lines selected for body weight from control lines, is largest in the first two weeks after weaning then it declines (16, 21, 41, 50).

Urrutia and Hayes (52), reviewed from McCarthy (28), increasing feed efficiency in the mice selected for increased efficiency of younger age (5 weeks) was mainly due to an increase in the feed consumption, while mice selected later age (10 weeks) the increase in efficiency came from reduction in the maintenance costs. Therefore selection for gain at later ages would rely on variation in maintenance costs.

Stephenson and Malik (45) measured maintenance requirements as the fixed levels of food intake were 1.25 and 1.35 g. of feed per gram of body weight per week in the selected line than in the controls respectively. They also found that the cost of depositing extra tissue to be lower in the selected lines than in the controls. Since control line loses unaccountable energy which could be used to increase growth efficiency in the selected lines.

#### **EFFECT OF SELECTION UNDER RESTRICTED FEEDING REGIME**

Timon and Eisen (50) observed greater differences in feed efficiency on a restricted level of feeding regime between a line selected for increased postweaning gain on ad libitum feeding regime and the control line. Stainer and Mount (44) and Yüksel et al. (54) observed better efficiency in lines selected under restricted feed intake.

The effect of the selection for growth under feed restriction on efficiency has been reported several authors. Falconer and Latyszewski (14) reported that the mice selected for increased body weight on a restricted diet were superior in weight gain after postweaning weight gain to the control and ad libitum lines when both groups were reared on a restricted diet.

McPhee et al. (31) found that under restricted feeding regime mice were more efficient than their controls. Urrutia and Hayes (52), designed an experiment to observe the effect of restricted feeding regime on the growth, after nine generation of selection for weight gain in two age intervals (early and late periods) and under ad libitum feed consumption or restricted consumption. In the early period of selection, they investigated that gross efficiency was higher in the ad libitum lines than restricted lines and controls. But it was not significant. In the late period of selection, gross efficiency was significantly higher in the restricted line than the others. In this period, ad libitum line had the lowest gross efficiency. Therefore they concluded that

selection for postweaning gain was more successful under ad libitum conditions at an early age while selection under restriction was more successful at a later age.

Yüksel et al. (54) designed an experiment, in order to perform a selection for increased efficiency under restricted and ad libitum at two ages. After 8 generations of selection, they found that there was no difference in efficiency between the lines at both ages. However their selected lines were more efficient than the controls.

Hetzel and Nicholas (21) found that although mice selected under restricted feed regime grew more than 25 % full feed mice. They reported that there was no difference in the efficiency among each others.

Those experimental evidence suggests that the selection under restricted feeding regime is more efficient than its control, but increase in efficiency seems to be lower than under full feeding regime efficiency.

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