RESEARCH NOTES

Relationships Between Income Minus Feed Cost and Residual Feed Consumption in Laying Hens

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ABSTRACT Residual feed consumption in laying hens is defined as the difference between observed feed intake and intake estimated from body weight, egg mass produced, and body weight change. Genetic and phenotypic relationships between residual feed consumption in the period of 21 to 40 wk of age (RFC) and income minus feed cost (IFC), egg mass (EM), egg number (EN), egg weight (EW), female body weight (BWF), feed efficiency (FE), age at first egg (AFE), and male body weight (BWM) were investigated on data of 8,844 hens and 1,138 cocks of brown egg layers, offspring of 427 sires and 1,945 dams. Restricted maximum likelihood estimates of the genetic correlations for an animal model among RFC and IFC, EM, EN, EW, BWF, FE, AFE, and BWM were .011, .306, .267, .085, .100, –.317, –.202, and .025, respectively. Heritabilities of .69 and .65 and a genetic correlation of .903 were found for observed feed consumption and estimated feed consumption, respectively. Residual feed consumption was found to be of only limited value as an additional selection trait to improve overall profitability of egg production, defined as income minus feed cost in a specified period of time.

(*Key words*: residual feed consumption, profitability, egg production, efficiency, selection)

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INTRODUCTION

To amend the selection criterion of a breeding scheme (commercial or experimental) with a new trait (source of information), it is not enough for this trait to have a reasonably high heritability and, thus, to offer some chance to show a selection response; it must also primarily contribute additional information to the anticipated objective of the program. For most commercial species, income minus feed cost is a trait of extraordinary importance for the economic success of a producer and, therefore, deserves attention from breeders. In laying hens, residual feed consumption in a specified period of time [i.e., the difference between observed feed intake and feed intake linearly estimated from egg mass produced, body weight (maintenance requirement), and body weight change] is sometimes thought of as a trait that could be used in a selection scheme to improve efficiency of feed use, either measured as feed conversion ratio, feed:egg mass produced, or its reciprocal, feed efficiency. There is the hope that from this trait more insight into supposed genetic differences in efficiency of physiological pathways might be gained. However, it should be noted that residual feed consumption is solely a linear combination of other traits. Therefore, it does not contain additional information about the breeding objective beyond the amount already present in the single traits of which it is composed. However, these traits could directly be included into a selection criterion, e.g., a selection index. It has been shown experimentally (Bordas *et al.*, 1992) that selection for negative residuals improved feed efficiency of laying hens. However, it is well known that feed efficiency is only

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one, although with no doubt a major, part of the profitability of egg production as a whole. Until now, no investigation about the genetic relationship between income minus feed cost and residual feed consumption has been published, although this would be of interest, because profitability of egg production seems to be more closely linked to income minus feed cost than to residual feed consumption. Clarification of the relationships is necessary before residual feed consumption, or any other trait, is integrated into a selection criterion. The aim of the investigation was to estimate genetic and phenotypic relationships between residual feed consumption and production traits, in particular income minus feed cost, in brown egg layers from data of a selection experiment designed to directly improve income minus feed cost in the period of 21 to 40 wk of age.

MATERIALS AND METHODS

Data for the investigation came from a selection experiment designed to genetically improve the trait "income minus feed cost between 21 and 40 wk of age (IFC)" in brown egg layers (Hagger, 1990, 1992). Eggs that weighed ≥70, 65 to 69, 60 to 64, 55 to 59, 50 to 54, 45 to 49, and ≤44 g were assigned relative prices of 1.30, 1.15, 1.10, 1.0, .90, .70, and .50, respectively. The relative values of a hen's eggs were summed to get the value of that hen's egg production for the test period. A price of .18 monetary units for an egg of Weight Class 4 and a price of .65 monetary units per kilogram of feed was used to calculate actual values of IFC. The base population was from a commercial cross between 50 Rhode Island Red males and 303 White Plymouth Rock females. Hens were selected for five generations on their IFC performance followed by two generations of selection on a best linear unbiased prediction breeding value for the same trait including the restriction of no genetic change in egg weight (Quaas and Henderson, 1976). Breeding values were estimated by the method of Quaas and Pollak (1980). The experiment consisted of two replicate selection lines and an unselected control line, all of the same origin. In all lines, 20 male and 80 female breeders were used in each generation.

Egg number and egg weight were recorded daily from onset of lay until 25 wk of age and on 6 d/wk thereafter. Egg production data were adjusted to 28-d periods for missing test days based on the hen's own performance on rate of lay and egg weight. Individual feed consumption from *ad libitum* access was recorded continuously for all hens from 21 to 60 wk. All birds were weighed at 10, 20, 30, 40, and 60 (hens only) wk. More details on husbandry of birds and the selection criterion are given elsewhere (Hagger, 1990, 1992, 1994). Altogether, 8,844 hens that had survived to 40 wk and that had eaten less than 10 kg feed/kg of egg mass produced and records of 1,138 cocks were included in the investigation. The restriction on feed conversion ratio was used to remove a few ill and molting hens. The birds were offspring of 437 sires and 1,945 dams. Data of hens were adjusted for effects of hatch and laying house within year prior to the analysis.

Residual feed consumption in the test period of 21 to 40 wk (RFC) was calculated for each hen as the difference between observed minus estimated feed intake, where the latter quantity was calculated by a multiple linear regression including body weight at 30 wk (maintenance requirement), egg mass produced between 21 and 40 wk, and body weight change in the same period. Regression coefficients were estimated from the combined data of all lines within a year. Such a within-year estimation of RFC was also used in the selection experiment for this trait described by Bordas *et al.* (1992). Variance and covariance components were estimated bivariately, i.e., RFC with one other trait at a time, with the restricted maximum likelihood method (Patterson and Thompson, 1971) for an animal model (Quaas and Pollak, 1980). Genetic and phenotypic correlations were then calculated for the combinations of RFC with IFC, egg mass (EM), egg number (EN), egg weight (EW), feed efficiency (FE), i.e., kilograms of egg mass produced per kilogram feed consumed, all these traits for the period of 21 to 40 wk, and then with body weight of hens at 40 wk (BWF) and age at first egg (AFE). The genetic correlation between RFC and body weight of cocks at 40 wk (BWM) was estimated by the approach of Tixier-Boichard *et al.* (1992) and Hagger (1994). The DFREML computer programs of Meyer (1991) were used.

RESULTS AND DISCUSSION

A high heritability of .49 was found for RFC from the combined data set. This estimate is nearly identical to the average of the single generation least squares estimates of the first five generations of the selection experiment (Hagger, 1991). Other estimates for this trait are .48 (Luiting and Urff, 1991) (704 hens), .27 (Tixier-Boichard *et al.*, 1992) (3,780 hens), and .52 (Bentsen, 1983) (471 hens). The last author also looked at %RFC, defined as RFC relative to the estimated feed intake. This trait had a heritability of .48 (471 hens) and a genetic correlation of .99 to RFC; thus, representing almost exactly the same trait. Katle and Kolstad (1991) estimated a heritability of %RFC of .64 (543 hens) and observed realized heritabilities between .35 and .57. From all these figures it can be concluded that RFC is moderately to highly heritable; therefore, it could be regarded as a valuable candidate trait to be included into a selection scheme.

No genetic correlation between RFC and IFC was found in the present data (Table 1). This suggests that RFC might be of rather limited value to amend the selection criterion of a commercial layer breeding scheme with the aim to genetically improve the economics of egg production. The traits EM and BW contribute substantially to IFC, thus, if the contributions of these two traits to feed intake are eliminated, not much can be left over in RFC that could induce a strong genetic correlation between RFC and IFC. It would be necessary to investigate how the information contained in RFC, mainly that on feed intake, could be included in a more promising manner into a selection criterion. It seems that either a combined trait like IFC or some enlargement of a classical selection index could be the solution. The phenotypic correlation between the two traits was slightly negative (Table 1); thus, pointing to the expected relation of negative RFC values with increasing IFC. The genetic correlation between feed intake and estimated feed intake was positive and very high, .903. The heritabilities of these two traits were .69 and .65, respectively. The high heritability of the latter trait must be a consequence of being a combination of at least two traits with high heritability, i.e., BWF with .73 (Hagger, 1994) and EM with .39 (unpublished data), that can be seen by inspection of the formula for the variance of a sum. The traits BWF and EM must substantially influence the observed feed intake and thus contribute to the high heritability of this trait and also to the high genetic correlation between feed intake and RFC.

The genetic and phenotypic correlations between RFC and other traits are given in Table 1. The genetic correlation between RFC and EM was still moderate and positive, whereas the one between RFC and BWF was much lower. The rather strong and positive relationship between RFC and EM indicates that selection gain in EM would, on average, be associated with a positive genetic gain in RFC. Tixier-Boichard *et al.* (1992) reported a negative estimate, –.17, between RFC and BWF. Nevertheless, the conclusion from the two estimates might be that the genetic relationship between these two traits is rather loose. The low genetic correlation between RFC and EW is in accordance with Tixier-Boichard *et al.* (1992). The positive genetic

TABLE 1. Genetic (r_g) and phenotypic (r_p) correlations between residual feed consumption, and income minus feed cost (IFC), egg mass (EM), egg number (EN), egg weight (EW), body weight of hens (BWF), feed efficiency (FE), age at first egg (AFE), and body weight of cocks (BWM)

	Trait							
	IFC	EM	EN	EW	BWF	FE	AFE	BWM
r_g	.011	.306	.276	.085	.100	–.317	–.202	.025
r_p	–.191	.021	–.001	.038	.062	–.415	–.128	. . .

correlation between RFC and EN is interesting and again in accordance with the latter authors. A genetic increase for EN would, thus, as already seen for EM, have on average a positive, i.e., undesired, genetic increase in RFC as a consequence. The negative genetic correlation between RFC and AFE would act in the same direction, because the earlier egg production starts, the more eggs can be produced in the period including this event. Bentsen (1983) had also found a negative genetic relationship for the two traits.

The genetic correlation between RFC and FE is negative as expected and again in accordance with Tixier-Boichard *et al.* (1992). Overall, the genetic correlations between RFC and other economically important female traits are in rather good agreement with the estimates from the study of Tixier-Boichard *et al.* (1992), the only study that is also based on a satisfactory number of observations to estimate genetic parameters. The genetic relationships between RFC and these traits can, thus, be given some confidence. According to these parameters, selection for negative values of RFC would genetically improve feed efficiency, but, on the other hand, genetically reduce EM and EN and, therefore, might leave IFC breeding values nearly unchanged, as confirmed by the estimated genetic correlation of zero (Table 1). In summary, selection for RFC does not seem to be a very promising approach for improving the profitability of egg production.

No genetic correlation between RFC and BWM was found, whereas Tixier-Boichard *et al.* (1992) reported a value of −.22. It has to be pointed out that this estimate will be associated with a larger sampling error than the others, because considerably fewer cocks than hens were recorded and the two traits are never observed on the same animals. The highest genetic relationship between two informative animals will be .5. No phenotypic relationships of practical importance were found between RFC, and EM, EN, EW and BW, and distinct negative values were observed between RFC and IFC, FE, and AFE (Table 1).

ADDENDUM

The formal relationships between RFC and its component traits have now been given by Kennedy *et al.* (1993).

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