BIOECONOMIC IMPORTANCE OF OPTIMUM LIFETIME REPRODUCTIVE PERFORMANCE IN ANIMAL BREEDING PROGRAMS: RESULTS FROM MICE

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SUMMARY

Data from 27 crosses of mice (430 matings) were utilized to evaluate the importance of certain biological traits associated with reproduction of parents and postweaning growth and carcass composition of progeny on economic conversion (ECN; expenses/income). The traits studied were reproductive rate (RRT), weight per pup born alive (WPP), parental feed consumption per day (FPD), age of parents at termination of reproduction (AGE), progeny postweaning average daily gain (ADG), progeny postweaning feed conversion (FCN), progeny postweaning survival (PWS), and carcass protein yield (PYD). Standard partial regression coefficients of ECN on the above 8 traits were estimated; the 8 traits accounted for 92% of the variation in ECN. The characters were negatively associated with ECN, showing that increased production contributes to minimizing ECN. Traits associated with increased cost and/or time of measurement (FPD,ADG,FCN,PYD) might be dropped from the phenotypic production function without loss of accuracy in predicting ECN.

INTRODUCTION

The primary objective of any animal breeding program should be the production of individuals capable of maximizing profit (income - expenses), or minimizing cost per unit of product, or economic conversion, defined as the ratio of expenses to income (Newman et al., 1985a). Various strategies for the development of comprehensive breeding programs have been reported in the literature (e.g., Brascamp, 1978; Dickerson, 1982; Harris et al., 1984).

Development of selection objectives should include both the genetic and economic aspects of the production system. Characters measured on parents and their progeny must be viewed in terms of their importance to economic conversion. There is no one superior indicator of economic conversion, and it will be a combination of numerous traits from parents and offspring, involving both biological "primary" traits (e.g., reproductive rate or progeny average daily gain), and monetary inputs into and outputs from the production system that determines "best" in terms of minimum cost per unit of product. Therefore, the objective of the present study was to elucidate the importance of certain biological traits in predicting economic conversion.

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EXPERIMENTAL PROCEDURE

Twenty-seven crosses (3 pureline, 6 two-way, 6 three-way, 12 backcross) from 3 random-mating, unselected strains of mice (SWO, J, PGH) were cohabited at 40 days of age and mated continuously and monogamously for a 365 day reproduction period to evaluate lifetime reproductive performance of the parents and postweaning growth and carcass composition of the progeny. A total of 432 matings (16 per pureline or cross) were made; 430 were utilized for the present study. A bioeconomic objective (Newman et al., 1985a) was used to estimate economic conversion for each cross for each set of constraints imposed by a culling procedure involving various levels of number of litters produced by a mating, age of parents at weaning of litter i, and the time (in days) from weaning litter i to birth of litter i+1. Further details of the experiment can be found in Newman et al., (1985b).

The 8 biological characters considered to be important in contributing to economic conversion (ECN) were (1) Reproductive rate (RRT)- the ratio of cumulative (over litters) number born alive to cumulative birth to birth interval; (2) Weight per pup born alive (WPP)- the ratio of cumulative (over litters) litter weight at weaning to cumulative number born alive (WPP is a measure of maternal ability, including lactation); (3) Parental feed consumption per day (FPD); (4) Age of parents at termination of reproduction (AGE); (5) Progeny postweaning average daily gain (ADG)- a measure of total growth in live weight, measured from 21 to 42 days of age; (6) Progeny postweaning feed conversion (FCN)- the ratio of feed intake to gain; (7) Progeny postweaning survival (PWS); (8) Carcass protein (lean) yield at 42 days (PYD)- reflecting composition of live weight. Parity effects on these traits have been published elsewhere (Newman et al., 1985 c,d), as have genetic and heterosis effects (Newman et al., 1986a,b).

Residual correlations were utilized to calculate standard partial regression coefficients for the biological components of ECN. As estimated, these correlations reflect the association across matings (parental pairs) within crosses. Thus, the experimental units for this analysis was the 430 matings in the experiment. An optimum culling rule was determined mating by mating and all variables were calculated relative to that rule. All variables were measured as averages across litters. The model used to analyze this data was similar to the model described by Newman et al., (1986a) for the estimation of genetic and heterosis effects.

RESULTS

Stepwise standard partial regression coefficients for economic conversion (ECN) and its 8 biological components are presented in table 1. Each line of the table represents the model derived for each additional trait added, along with the corresponding r-square (multiple coefficient of determination) resulting from the combined association of all variables included. The variable added at each step is the one which results in the greatest increase in r-square. The last line of the table, labelled "contribution", is the amount by which r-square would be reduced if the variable heading the

TABLE 1. STANDARD PARTIAL REGRESSION COEFFICIENTS FOR TRAITS ASSOCIATED WITH ECONOMIC CONVERSION[a]

Added trait	r-square	PYD	RRT	WPP	FCN	PWS	AGE	FPD	ADG
PYD	.819	-.905							
RRT	.859	-.785	-.233						
WPP	.878	-.617	-.279	-.202					
FCN	.895	-.706	-.301	-.269	.202				
PWS	.907	-.524	-.234	-.189	.260	-.345			
AGE	.912	-.478	-.234	-.197	.243	-.335	-.082		
FPD	.919	-.480	-.280	-.220	.252	-.324	-.108	.104	
ADG	.920	-.480	-.280	-.218	.251	-.289	-.108	.103	-.039
Contribution		.035	.036	.015	.023	.005	.009	.008	.000

[a]See text for meaning of acronyms. All regression coefficients different from zero (P<.01) except ADG (P<.28). Contribution is the amount by which r-square would be reduced if that variable were removed from the regression equation (for model with largest r-square).

column were removed from the regression equation. The contribution is presented only for the last model with the highest r-square. The 8 traits accounted for 92% of the variation in ECN. This value may be artificially high because ECN is estimated directly from the traits themselves rather than from cost and value considerations. Regression coefficients were positive for feed conversion (FCN) and parental feed consumption (FPD). These traits are inputs, or expenses and are related to the numerator of ECN. All other traits expressed negative coefficients. These traits are most closely associated with the denominator of ECN, or outputs from the system. The coefficient for average daily gain (ADG) was not significantly different from zero; in addition, ADG did not contribute to a large increase in r-square. All other regression coefficients were significantly different from zero (P<.01). Correlation coefficients are presented in table 2. All of the correlations between the 8 components and ECN are negative, indicating that increases in component traits will decrease ECN. Protein yield (PYD) had the largest correlation with ECN. Increased ADG and FCN led to increased PYD and smaller ECN. The progeny that survive postweaning feeding (PWS) will contribute more income to the system than dead individuals. The number of individuals available for postweaning growth is a function of RRT of the mating and WPP. The length of time a mated pair can efficiently produce offspring (AGE) also becomes a major component in minimizing ECN, and, to a lesser extent, FPD to support increased reproduction.

TABLE 2. RESIDUAL CORRELATION COEFFICIENTS FOR TRAITS ASSOCIATED WITH ECONOMIC CONVERSION

	PYD	RRT	WPP	FCN	PWS	AGE	FPD	ADG
RRT	.51							
WPP	.72	.20						
FCN	.73	.40	.67					
PWS	.91	.58	.76	.78				
AGE	.45	.25	.26	.23	.40			
FPD	.35	.46	.25	.22	.36	.36		
ADG	.84	.53	.72	.71	.92	.35	.32	
ECN	-.91	-.64	-.70	-.61	-.90	-.48	-.35	-.84

DISCUSSION

An important question to ask is "which of the 8 components is the most important contributor to ECN?". There are three ways that the 8 components of ECN may be ranked: (1) based upon simple correlations with ECN; (2) based upon standard partial regression coefficients, and (3) based upon contribution to r-square. Based upon (1), the ranking (from largest negative correlation to the smallest, signifying greater association with ECN) would be PYD, PWS, ADG, WPP, RRT, FCN, AGE and FPD. Based upon standard partial regression coefficients (in order of absolute value) the ranking would be PYD, PWS, RRT, FCN, WPP, AGE, FPD and ADG. Based upon largest contribution to r-square, the ranking would be RRT, PYD, FCN, WPP, AGE, FPD, PWS and ADG. There seem to be rather large discrepancies among the rankings between groups, thus Spearman's coefficient of rank correlation (Steele and Torrie, 1980) was utilized to test for measures of correspondence between ranks. Rank correlations between simple correlations (1), regression coefficients (2) and contribution to r-square (3) were .57 ($P<.25$) for (1) with (2); 0 ($P<.50$) for (1) with (3); .60 ($P<.25$) for (2) with (3). Thus, each grouping has its own importance and is dependent upon whether the purpose is to study prediction or cause and effect relationships. Correlations are useful for one-at-a-time predictive purposes, and give an indication of how well one can predict ECN with single traits. Alternatively, the regression coefficients are intended to measure simultaneous cause and effect relationships and, at least for predictive purposes, the direct applicability to prediction of ECN is not as apparent, in part due to the high correlations among the indirect relationships of the traits. This has given rise to positive correlations between a dependent and independent variable when the regression was estimated to be negative.

Finally, the usefulness of the contribution each trait makes to r-square can aid in (1) determining the cost of data collection, i.e., "how much information can be gained (or lost) by inclusion (or removal) of one trait in the model?", and (2) evaluating the long-term usefulness of the bioeconomic model for actual livestock production systems. The cost of measurement of certain attributes in the system may make it less profitable. Four of the 8 component traits that require extra cost and labor to measure are FPD, FCN, ADG and PYD. It has been shown that fat and bone determination are not necessary to derive a useful indicator of PYD (Newman 1983); wet carcass weight will predict PYD with 99% accuracy. There is no one good indicator of lean content available for live animal evaluation. Measuring feed consumption on parents (FPD) and progeny and weighing progeny to estimate FCN and ADG will be costly and time consuming. Note that the correlation between FCN and ADG is .71, thus ADG could be used as a predictor of FCN, thus eliminating the need to measure feed intake on the progeny.

How well can we predict ECN based upon traits that are easy to measure? Utilizing RRT, WPP, AGE and PWS, the r-square becomes .86, a reduction of about 8% relative to the r-square for the complete model of .92. Inclusion of ADG into the equation does not change the r-square value. It may not be useful to measure FPD, ADG, FCN and PYD, yet the remaining traits (RRT, WPP, AGE and PWS), although easy and inexpensive to measure, are lowly heritable and response to selection would be slow if based upon a criteria containing only these traits. Alternatively, these remaining traits do express varying levels of heterosis (Newman et al., 1986a,b).

It was the intent of the present study to utilize the laboratory mouse as a biological model for meat animals, especially swine. The present study departed from actual swine production practices in that (1) breeding females produced, on average, a larger number of litters; (2) males and females were mated continuously and monogamously, and (3) progeny were evaluated to an age-constant slaughter basis rather than a weight-constant basis as is usual in market hog production. It has been observed that the major components of ECN seem to be high RRT and PYD. All costs associated with producing pork can be decreased by increasing number born alive (Tess et al., 1983a). Furthermore, costs per kg of carcass lean can be decreased to a greater extent based upon age-constant slaughter (Tess et al., 1983b). Also, growth rate in the present study (as measured by ADG and FCN) was not a major factor in determining minimum ECN. PYD does relate to lean growth per day. Tess et al., (1983b) reported that cost per kg of live weight from faster growing animals is reduced only for non-feed inputs for age-constant slaughter.

The potential importance of increased RRT and PYD should be taken into consideration when designing breeding systems for overall long-term efficiency but should be flexible enough to incorporate changes in marketing standards.

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