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Breeding goals for intensive but sustainable poultry meat production

F.R. LEENSTRA AND D.A. EHLHARDT

DLO Institute of Animal Science and Health (ID-DLO) Beekbergen, P.O. Box 15, NL-7360 AA Beekbergen, The Netherlands

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Abstract

The effects of selecting male parent breeding stock for efficiency of feed utilization (EFU) were compared with those of selection for body weight (BW). Selection for EFU resulted in an improved feed and protein efficiency at a certain fixed body weight when compared with BW selection. Correlated effects of selection for EFU (slaughter yield, viability, parent stock fertility) were favourable. For sustainable poultry meat production, losses in the production cycle through manure, slaughter offals and mortality should be minimized. The results of experimental selection indicate that selection for EFU may be a useful tool towards decreasing losses in poultry meat production.

Keywords: broilers, selection, feed efficiency, correlated responses

Introduction

Sustainability of animal production is under scrutiny in different parts of the world. In the industrialized and densely populated areas of Western Europe and North America, poultry meat production at farm level is associated with high external inputs, turnover rates and economic efficiency. However, in addition minimal waste production (manure, mortality) is required for a sustainable poultry meat production.

Efficiency of feed utilization (EFU), high fertility, low mortality and high slaughter yields are determining factors in minimizing waste production. Selection for growth rate has increased EFU as a correlated effect, but has recently been recognized to produce a number of unfavourable side effects: reduced fertility of parent stock, increased perinatal mortality and increasing losses from physiological insufficiencies. Carcass fat content increased notably, resulting in more trimming and consequently lower yield of marketable product. Losses at the processing plant further include increased incidence of birds dead on arrival and condemnations owing to bone fracture and skin lesions as a result of pressure contact with moist litter. The increased losses during the production process not only imply increased waste production, but are also undesirable from an ethical point of view. In a broader sense they affect product acceptability.

In general, the increased losses point to a disequilibrium of physical functions, especially detrimental for the skeleton and the circulatory system. A more balanced breeding goal, aimed at total yield and minimal losses, might support sustainable production more than extreme capacities in weight gain only. How this balance can be obtained is the major problem in poultry breeding.

Because of its beneficial effect on production costs and carcass composition, EFU is an attractive selection criterion considered by most breeding companies. In addition it is a complex trait, addressing many different mechanisms, such as the growth curve, digestive ability and body composition (Pym, 1990), that might provide a more balanced selection result. In this paper, selection for EFU is compared with selection for body weight with regard to sustainable poultry meat production.

Experimental selection lines

At COVP-DLO, broiler sire type lines derived from the same base population were selected for body weight at 6 wk of age (GL line) or for feed efficiency from 3 to 6 wk of age (FC line). In both lines simple mass selection was applied. In the GL line, about 25-30% of the males and 30-35% of the females were selected each generation. In the FC line this was 30-35% for males and 45-50% for females (see Leenstra, 1988a, for details of selection methods and estimated genetic parameters).

Consequences of selection

The lines were compared at several stages of the selection programme, either as pure lines or as sire strain in a broiler cross. In some cases commercial broilers were included in comparisons. Effects on different aspects of efficiency, such as feed required for a fixed body weight, slaughter yields, nitrogen efficiency, mortality, fertility, and adaptation to high environmental temperatures, were examined. All comparisons were based on group means, analysed by ANOVA. Differences mentioned in the text were significant ($P < 0.05$).

Feed efficiency and slaughter yields

Progeny from sires of the 7th and 9th generation were reared to similar weight and EFU and slaughter yields were determined (Table 1). FC progeny required less feed for a given body weight and had an equal (G7) or higher (G9) percentage of breast meat, the most valuable part of the broiler carcass, and less abdominal fat, the largest fat deposit in broilers, increasingly discarded as waste.

Nitrogen efficiency

About 60% of the nitrogen excreted is voided in the form of uric acid, which is easily converted to ammonia. Nitrogen excretion, through its effects on ammonia produc-

Table 1. Age, body weight, feed efficiency and slaughter yields of progeny of sires from a weight-selected line (GL) or a line selected for feed efficiency (FC) mated to commercial broiler breeder dams, repeated in generations 7 and 9.

	Age (d)	Weight (g)	Feed efficiency	Slaughter yield (%)	Brest meat (%)	Abdominal fat (%)
Generation 7[a]						
GL sire	42	1801	0.56	70.4	13.5	2.98
FC sire	44	1774	0.58	59.8	13.6	2.37
Generation 9[b]						
GL sire	44	2187	0.59	65.1	13.6	3.17
FC sire	47	2141	0.61	66.0	14.4	2.38

[a] Eight groups of 10 chickens per line.
[b] Four groups of 180 chickens per line; for slaughter yields, four groups of 20.

Table 2. Nitrogen intake, deposition and excretion (expressed in g per kg of live weight) and nitrogen efficiency, all at a weight of 2100 g, of chickens of a line selected for body weight (GL) and of a line selected for feed efficiency (FC) and of progeny of sires of these lines and broiler breeder dams (see Table 1 for group sizes).

	N intake	N deposition	N excretion	N efficiency
G 7[a]				
GL line	74.7	30.4	44.3	0.407
FC line	69.8	31.7	38.1	0.454
G 9 sires[b]				
GL line	58.2	24.2	34.0	0.416
FC sire	56.5	25.1	31.4	0.444

[a] Pure lines, feathers included in N deposition, diet with 25.8% protein.
[b] Cross-breeds, feathers included in N excretion, diet with 21% protein.

tion, is one of the major factors contributing to pollution in broiler production. In the 7th generation, the pure lines were compared for nitrogen efficiency on a diet with a high protein content (25.8%). In the 9th generation, nitrogen efficiency of progeny of GL and FC sires, fed a normal diet (21% protein), was determined (Table 2).

FC chickens required less feed for a fixed body weight than GL chickens. Consequently their nitrogen intake was lower. Nitrogen deposition in FC chickens was higher irrespective of whether feathers were included in the carcass analysis. The higher N efficiency of FC chickens was caused by a lower N intake and a higher N deposition.

In the 11th generation, pure FC chickens were compared for nitrogen balance with commercial broilers. To evaluate the potential effects of dietary composition and selection for EFU, the broilers received a standard diet and a diet adapted to minimize N excretion. The FC chickens received only the adapted diet (Ten Doeschate, 1992; Table 3). From the data in Table 3 it is clear that the effects of genotype on nitrogen balance were greater than those of dietary composition.

Table 3. Nitrogen intake and excretion (in g) and nitrogen efficiency dependent on diet and genotype calculated by interpolation for a nitrogen deposition of 26 g kg^{-1} live weight in male chickens.

Diet	Genotype	N intake	N excretion	N efficiency
Control	Commercial (C)	56.4	30.4	0.461
Adapted	Commercial (C)	52.9	26.9	0.491
Adapted	FC	45.9	19.9	0.566

Table 4. Nitrogen intake, deposition and excretion in manure and through ammonia (all in g kg^{-1} at a body weight of 2100 g) and nitrogen efficiency (three groups of 300 chicks per genotype).

Genotype	N intake	N deposition	N manure	N ammonia	N efficiency
C sire x C dam	57.9	25.1	20.9	7.8	0.434
FC sire x C dam	56.9	25.6	18.0	8.7	0.450
FC sire x FC dam	54.5	236.2	15.7	6.7	0.481

In the 13th generation, pure FC chickens were compared for N balance with commercial broilers and with progeny of FC males and the same dams as used for the commercial broilers. N intake, deposition in the carcass, excretion in the manure and emission as ammonia were determined for a weight of 2100 g by interpolation (Table 4). The commercial broilers needed 41 d to attain this weight, the pure FC chickens 49 d.

The pure FC chickens had a lower nitrogen intake and a higher nitrogen deposition than the commercial broilers. The FC x commercial cross was intermediate. The genotypes also differed in N excretion, although total ammonia emission from the pens did not differ. A possible explanation is a faster rate of uric acid degradation by more agitation (aeration) of the litter by the more active FC chickens.

Mortality

In most experiments chick numbers were too small and mortality too low to evaluate possible differences in mortality. However, in each generation, 1200 chicks of both selection lines were reared for selection purposes. Mortality over generations 9 to 12 indicated increasing differences between the lines (Table 5).
Differences in mortality were most apparent for heart failure syndrome and ascites, but also differences in colisepticaemia and in respiratory problems (both often associated with response to vaccination against Newcastle Disease) were considerable. In addition, the GL line showed a much higher frequency of otherwise-viable birds with leg problems.

Fertility

Egg production was determined in each generation in 100-140 hens per line. During

Table 5. Mortality (% of chicks started) in the 9th to 12th generations of a weight- selected line (GL) and a line selected for feed efficiency (FC).

	GL line				FC line			
Generation	9	10	11	12	9	10	11	12
Mortality (total)	5.7	9.2	7.2	7.4[a]	3.1	2.1	2.0	2.0
Hearth failure ans ascites	4.0	5.7	4.1	4.1	2.0	1.4	0.8	1.3
Leg weakness	0.8	0.6	1.1	0.3	0.2	0.3	0	0.1
Colisepticaemia	0	1.0	0.5	1.0	0.1	0.3	0.3	0.4
Respiratory problems	0.7	1.3	0.4	0.7	0.4	0.2	0.1	0

[a] In addition, 3.4% of the GL chickens died of symptoms similar to body hepatitis inclusion virus. FC chickens housed in the same room showed no symptoms.

Table 6. Fertility and hatchability in reciprocal crosses between a line selected for body weight (GL) and a line selected for feed efficiency (FC).

SIRE	GL	GL	FC	FC
DAM	GL	FC	GL	FC
% Fertile/eggs set	92.0	95.6	95.5	95.2
% Hatch/eggs set	59.0	74.4	66.4	70.8

the selection experiment, differences in egg production developed between the two lines. In the 5th generation GL hens produced 97 hatching eggs per hen, while FC hens produced 122 hatching eggs per hen. In the 11th generation, GL hens laid 101 hatching eggs and FC hens 135. Egg weight was higher among GL hens, as was the frequency of abnormal eggs.

In the 12th generation, a reciprocal cross between the two lines was made, using AI. Twelve males and 48 females of each line were used. For experimental reasons, hatching eggs had to be collected for 3 wk. Consequently embryonic mortality was high and thus indicative for embryonic fitness (Table 6). There was a significant effect of sire and dam line on fertility and hatchability. Both FC sires and FC dams had a higher fertility. The effect of dam on hatchability was pronounced.

Adaptation to high temperatures

In moderate climates heat stress is only incidentally a problem. However, in large parts of the world heat stress occurs frequently. In both cases, resistance to heat stress is valuable because cooling of broiler houses requires energy resources. In the 11th generation, progeny of the GL and FC line were compared at moderate and continuously high temperatures (33°C at hatch to 20°C from 5 wk of age onwards versus 33°C to 32°C) (Cahaner & Leenstra, 1992). A clear genotype x environment interaction was present. Differences between the genotypes in the moderate climate were as expected (Leenstra & Cahaner, 1991). In the hot climate, however, FC progeny showed a higher growth rate than GL progeny. Differences in feed and protein effi-

Table 7. Body weight at moderate (6 wk) and high (8 wk) temperatures and feed and protein efficiency to a weight of 2100 g (moderate temperature) and to 8 wk of age (high temperature) of progeny of sires from a weight-selected line (GL) or a line selected for feed efficiency (FC) and broiler breeder dams (six groups of 12 chicks per genotype).

	Body weight		Feed efficiency		Protein efficiency	
Temperature	moderate	high	moderate	high	moderate	high
Age/weight	6 wk	8 wk	2100 g	8 wk	2100 g	8 wk
GI sire	2003	1670	0.59	0.48	0.42	0.34
FC sire	1789	1753	0.61	0.54	0.44	0.39

ciency consequently increased in favour of the FC progeny. Some data are summarized in Table 7.

Discussion

In broiler meat production, feed costs form about 70% of the total production costs. Other factors are costs of the one-day-old chick, housing, heating, ventilation, medication and labour. Mortality implies lost income, inefficient use of housing and extra labour. In the near future N excretion will be an additional cost factor in The Netherlands. A high growth rate implies a short rearing period and consequently a relatively low maintenance feed requirement and efficient use of housing, labour and capital invested. Slaughter yield, and especially the proportion of breast meat, determines the value of broilers for the processor.

Our experimental results indicate that, compared with selection for body weight, selection for EFU resulted in reduced feed costs (less feed for a fixed body weight), equal or better slaughter yields and lower mortality. Chick costs based on parental fertility will be equal or lower. Negative effects from heat stress might be lower. Important for areas with a high poultry density is the significant reduction in manure volume and nitrogen volatilized and leaked to the environment. Two aspects are not in favour of selection for EFU: the prolonged rearing period and the increased cost of selection itself. Selection for EFU requires higher investments and more labour than selection for body weight. However, owing to the high reproductive capacity of chickens, the costs of selection are spread over a large number of birds. Consequently, selection for EFU is very likely feasible (Leenstra, 1988b; Leenstra & Cahaner, 1992).

Nevertheless, selection for EFU is probably not widely applied in commercial stock, as the comparison of our experimental selection line with commercial stock indicates. In our experiments we selected for EFU only. In a commercial breeding programme it seems logical to select on body weight prior to a test for feed efficiency, as test capacity for feed efficiency will always be limited. When selection for EFU is based on an age-constant test period and no correction for initial body weight is made, as was the case in our FC line, the growth curve of the chickens is affected.

Pre-test growth rate is reduced and growth rate during the test period is relatively increased, compared with selection for body weight. These changes in growth curve might be the main cause of differences in viability and to some extent differences in efficiency (Leenstra, 1988b). Ascites, heart problems and possibly leg problems are related to early growth rate. The application of pre-selection for body weight at a very young age, followed by selection for feed efficiency, might have less favourable effects and is not advisable.

The direct and correlated effects of selection on EFU in an experimental situation indicate good possibilities for an environmentally acceptable poultry meat production. It should be possible to attain at least similar effects in a commercial breeding programme if poultry producers are willing to accept lower gains in growth rate.

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