Broiler Breeding Strategies Using Indirect Carcass Measurements

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ABSTRACT The objective of the current study was to determine the consequences of using indirect carcass measurements on the genetic response and rate of inbreeding in broiler breeding programs. In the base breeding scheme, selection candidates were evaluated based on direct carcass measurements on relatives. The possibilities of using indirect carcass measurements were investigated in alternative breeding schemes. Three alternative schemes, including indirect and own performance information for carcass traits on selection candidates, were evaluated by deterministic simulation. In the first scheme, indirect carcass traits were measured on male selection candidates. In the second scheme, indirect carcass traits were measured on male selection candidates, and direct carcass traits were measured on relatives. In the third scheme, indirect carcass traits were measured on male and female selection candidates, and direct carcass traits were measured on relatives. In the base scheme, the genetic response for breast muscle percentage (BMP) was 0.3%, and the rate of inbreeding was 0.96% per generation. In the third alternative scheme, the response for BMP increased by 66.2% compared with the base scheme, and the rate of inbreeding decreased to 0.79% per generation. The improved genetic gain resulted from increased accuracy of selection. The use of own performance information for selection candidates reduced the rate of inbreeding in alternative schemes, which is desirable for long-term selection. The accuracy of the indirect carcass measurements had consequences on the response for BMP and the rate of inbreeding. In most cases, an accuracy of 30% was sufficient to result in a higher gain for BMP and a lower rate of inbreeding as compared with the base scheme.

(*Key words*: broiler, carcass, deterministic simulation, indirect measurement, own performance)

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INTRODUCTION

The major aim of broiler breeding over the past 50 yr has been to improve growth rate, feed conversion, and meat yield. The poultry industry has traditionally evaluated broiler performance based on feed conversion and BW gain. However, strong consumer demand for breast meat has increased its value to the industry and led poultry producers to look for ways to optimize breast muscle growth (Ewart, 1993; Watts and Kennett, 1995). For many producers, breast yield is considered as important as growth rate and feed conversion (Baeza and Leclercq, 1998). Although growth rate and feed conversion can be recorded with live birds, birds have to be slaughtered to measure carcass traits. Consequently, selection of sires and dams for carcass traits is based only on information recorded from relatives and not based on their own performance. Selection based on information of relatives [e.g., best linear unbiased prediction (BLUP) selection] would increase the correlation between estimated breeding values (EBV) of relatives, resulting in a higher rate of inbreeding (Burrows, 1984; Bijma et al., 2001).

Indirect carcass measurements provide the opportunity to collect information from live birds and as a result the own performance information for carcass traits would be available on selection candidates. A range of indirect measurement methods is available. Some of these techniques use simple, inexpensive equipment, and others require sophisticated, expensive equipment (Latshaw and Bishop, 2001). Body conformation traits (i.e., breast width, length, and thickness) are good indicators for predicting breast muscle weight. The keel length shows a strong phenotypic correlation with the weight of breast muscle (0.8 in ducks and 0.7 in chicken and geese; Rymkiewicz

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Abbreviation Key: BLUP = best linear unbiased prediction; BMP = breast muscle percentage; CP = carcass percentage; CT scan = computed tomography scan; DCM = direct carcass measurement; EBV= estimated breeding value; FCA = adjusted feed conversion; FICM = female indirect carcass measurement; INBMP = indirect breast muscle percentage; INCP = indirect carcass percentage; MICM = male indirect carcass measurement; MRI = magnetic resonance imaging; r_g = genetic correlation.

and Bochno, 1999; Bochno et al., 2000). Moreover, Komender and Grashorn (1990) observed a high genetic correlation (0.62) between the thickness and weight of breast muscles in ducks. Those results were confirmed by other studies of chickens and geese (Rymkiewicz and Bochno, 1999). Originally, the thickness of breast muscle was measured using needle catheters, but recently ultrasonic apparatus has been employed. The results with both techniques show a similar correlation with the weight of breast muscle (Canope et al., 1997). More expensive but accurate techniques to assess body composition of live birds are: computed tomography scan (CT scan; Bentsen and Sehested, 1989; Remignon et al., 1997; Glasbey and Robinson, 2002), magnetic resonance imaging (MRI), and echography (Grashorn, 1996). Tang et al. (2002) found high phenotypic correlations for BW (r = 0.98), total adipose tissue (*r* = 0.99), and abdominal adipose tissue (*r* = 0.98) between MRI and dissection methods in rats.

Information is lacking on the minimum level of accuracy of indirect measurements of own performance that is required to justify incorporation in broiler breeding schemes. The objective of the present study was to determine the consequences of using indirect carcass measurements for the genetic response and rate of inbreeding in a broiler breeding program.

MATERIALS AND METHODS

Selection response and the rate of inbreeding were predicted by deterministic simulation of single-stage selection schemes with discrete generations, using the program SelAction (Rutten et al., 2002). The program accounts for reduction in variance due to selection (Bulmer, 1971) and corrects selection intensities for finite population size and for the correlation between index values of family members (Meuwissen, 1991). The program predicts the rate of genetic gain using multitrait pseudo-best linear unbiased prediction (Villanueva et al., 1993). SelAction uses a hierarchical mating structure in which dams are nested within sires, and random mating of selected animals is applied. Prediction of the rate of inbreeding is based on the long-term contribution theory, which was introduced by Wray and Thompson (1990) and further developed by Bijma and Woolliams (2000).

Population and Breeding Scheme

A population with discrete generations was simulated in which 100 males were randomly mated with 500 females with a mating ratio of 1 male to 5 females (Figure 1). Each female produced 24 offspring (12 males and 12 females). The total number of progeny of each sex was 500 × 12 = 6,000. All birds were reared in group housing until 3 wk of age (males and females separately). Then 50% of the males (3,000) were randomly assigned to the feed conversion test and moved to individual cages. At the end of the feed conversion test (6 wk), 100 males out of 3,000 available males were selected as parents for the next generation (selected proportion = 0.033). The remaining males were kept in the group housing until 6 wk of age and were then slaughtered to collect their direct carcass measurements (DCM) including carcass percentage (CP) and breast meat percentage (BMP). The female birds were weighed at 6 wk of age, and 500 females out of 6,000 available females were selected as parents for the next generation (selected proportion = 0.083). Selection intensities in males and females were chosen close to values in a practical broiler breeding program to take into account selection based on other traits such as reproduction and health, as is performed in practical breeding.

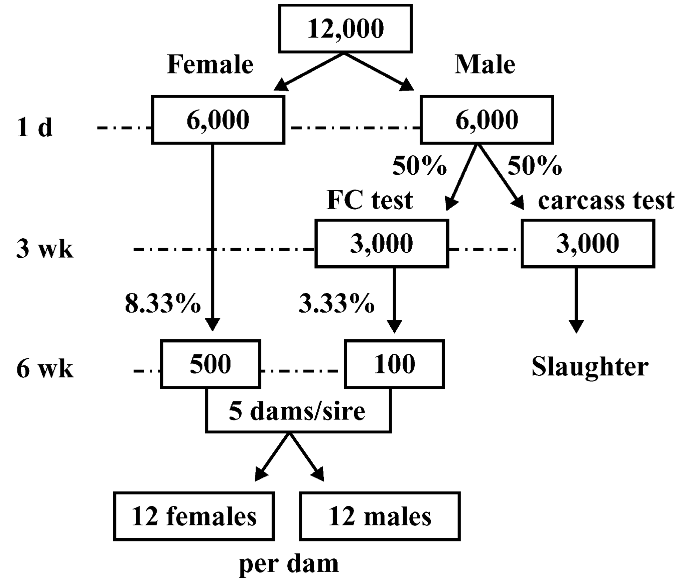

FIGURE 1. Base broiler breeding program, 50% of the male birds in feed conversion (FC) test and the other 50% in the carcass test.

The present breeding scheme was likely designed for a male line program, in which the breeding goal consisted of BW at 6 wk (BW_6), adjusted feed conversion (FCA = feed conversion adjusted for BW), and BMP:

$$H = EV_1 \times A_{BW_6} + EV_2 \times A_{FCA} + EV_3 \times A_{BMP}$$

where *H* is the breeding goal; EV_1, EV_2, and EV_3 are the economic values for BW_6, FCA, and BMP, respectively, and A_{BW_6}, A_{FCA}, and A_{BMP} were the true breeding values for BW_6, FCA, and BMP, respectively. Jiang et al. (1998) derived the economic values for BW_6 (0.33), FCA (–0.3), and BMP (0.06) based on profit equations. These economic values (euros/marketable bird per unit) were used for all breeding schemes.

Alternative Breeding Schemes

Three alternative breeding schemes were simulated to investigate the effect of indirect carcass measurements, including indirect carcass percentage (INCP) and indirect breast muscle percentage (INBMP), on genetic gain for BMP and the rate of inbreeding. First, methods with 100% accuracy of carcass measurement were evaluated to deter-

TABLE 1. The number of full-sib (FS) and half-sib (HS) birds available for different breeding strategies

Selection candidates (n)			Trait[2]											
			BW_6		FCA		BMP		CP		INBMP		INCP	
Scheme[1]	Males	Females	FS	HS	FS	HS	FS	HS	FS	HS	FS	HS	FS	HS
Base	3,000	6,000	17	70	5	25	6	24	6	24	—	—	—	—
A	3,000	6,000	11	48	5	24	—	—	—	—	5	24	5	24
B	3,000	6,000	17	70	5	24	6	24	6	24	5	24	5	24
C	3,000	6,000	17	70	5	24	6	24	6	24	16	70	16	70

[1]Base scheme = direct carcass measurements for male relatives; scheme A = indirect carcass measurements on male selection candidates; scheme B = indirect carcass measurements on male selection candidates as well as direct carcass measurements on male relatives; scheme C = indirect carcass measurements for male and female selection candidates as well as direct carcass measurements on male relatives.

[2]BW_6 = BW at 6 wk (kg); FCA = adjusted feed conversion (point); BMP = breast meat percentage (%); CP = carcass percentage (%); INBMP = indirect BMP measurement (%); INCP = indirect CP measurement (%).

mine the potential for using these techniques. Subsequently, indirect carcass methods with lower accuracy of measurements were investigated. The following alternative schemes were considered:

1. Scheme A: indirect carcass traits and direct (actual) feed conversion were measured on male selection candidates (3,000). The information on relatives for carcass and feed conversion traits was available for female selection candidates [male indirect carcass measurement scheme (MICM)].
2. Scheme B: in order to combine direct and indirect carcass measurements, indirect carcass traits and direct (actual) feed conversion were measured on male selection candidates (3,000) and direct carcass traits were measured on the remaining males (3,000) after slaughter. Consequently, sires were selected based on their own performance information for carcass and feed conversion as well as information on relatives for carcass traits. Dams were selected based on the information on relatives for carcass and feed conversion traits (MICM + DCM).
3. Scheme C: for further application of indirect carcass measurements in both sexes, indirect carcass traits were measured on male (3,000) and female (6,000) selection candidates. Direct (actual) feed conversion was measured on male selection candidates, and direct carcass traits were measured on the remaining males after slaughter. Therefore, sires were selected based on their own performance information for carcass and feed conversion traits as well as the information on relatives for carcass traits. Dams were selected based on their own performance information for carcass traits and the information on relatives for carcass and feed conversion traits [MICM + female indirect carcass measurement (FICM) + DCM].

Table 1 gives the traits recorded, and the number of full-sib and half-sib groups in the different breeding schemes. For BW_6, FCA, INBMP, and INCP, in addition to the average phenotypic performance of the full sibs and half sibs, the own performance of selection candidates was available. The BMP and CP were not available for selection candidates.

Accuracy of Indirect Measurements

The accuracy of the various indirect carcass methods differs. The MRI is a very accurate method (Scollan et al., 1998), whereas a method like ultrasound is less accurate (Stavrev, 1997). Accuracy of measurement influences the accuracy of selection and, subsequently, determines the genetic gain for breeding goal traits. To investigate the effect of accuracy of indirect measurements on genetic gain and the rate of inbreeding, a range of accuracy from 100 to 20% was simulated in alternative schemes.

Genetic Parameters

Except for indirect carcass traits (INCP and INBMP), the genetic parameters of the traits in the simulation were based on an analysis of actual experiments, including birds kept in group housing for the carcass test and birds kept in individual cages for the feed conversion test (Ask et al., 2002; Zerehdaran et al., 2004). The accuracy of indi-

TABLE 2. Phenotypic variances, economic values and genetic parameters of traits used in simulation study

Traits[1]	V_P[2]	EV (euro)[3]	Genetic parameters[4]					
			BW_6	FCA	BMP	CP	INBMP	INCP
BW_6 (kg)	0.06	0.33	0.35	0.05	0.15	0.16	0.15	0.16
FCA (point)	0.17	–0.3	0.04	0.41	0.03	0.26	0.03	0.26
BMP (%)	0.95	0.06	0.18	0.01	0.48	0.60	1.00	0.60
CP (%)	0.92	—	0.12	0.02	0.55	0.42	0.60	1.00
INBMP (%)	0.95	—	0.18	0.01	1.00	0.55	0.48	0.60
INCP (%)	0.92	—	0.12	0.02	0.55	1.00	0.55	0.42

[1]BW_6 = BW at 6 wk (kg); FCA = adjusted feed conversion (point); BMP = breast meat percentage (%); CP = carcass percentage (%); INBMP = indirect BMP measurement (%); INCP = indirect CP measurement (the accuracy of indirect measurement for INBMP and INCP is 100%).

[2]V_P = phenotypic variance.

[3]EV = economic value (euros/marketable bird unit).

[4]Heritabilities are given on the diagonal and genetic and phenotypic correlations are given above and below the diagonal, respectively. The SE for heritabilities was in the range of 0.02 to 0.09, for genetic correlations was in the range of 0.03 to 0.15, and for phenotypic correlations was in the range of 0.03 to 0.05. The estimated parameters are based on 100% accuracy of indirect measurements for INBMP and INCP.

TABLE 3. Economic and genetic responses of breeding goal traits and rate of inbreeding of different schemes

Scheme[1]	Traits in index[2]	Description[3]	Response[4]				
			ΔG	BW_6	FCA	BMP	ΔF[5]
Base	BW_6, FCA, BMP, CP	DCM	0.106	0.076	–0.211	0.296	0.963
A	BW_6, FCA, INBMP, INCP	MICM	0.110	0.075	–0.209	0.380	0.852
B	BW_6, FCA, BMP, CP, INBMP, INCP	MICM + DCM	0.112	0.075	–0.208	0.412	0.853
C	BW_6, FCA, BMP, CP, INBMP, INCP	MICM + FICM + DCM	0.116	0.073	–0.207	0.492	0.789

[1]Base scheme = direct carcass measurements for male relatives; scheme A = indirect carcass measurements on male selection candidates; scheme B = indirect carcass measurements on male selection candidates as well as direct carcass measurements on male relatives; scheme C = indirect carcass measurements for male and female selection candidates as well as direct carcass measurements on male relatives.

[2]BW_6 = BW at 6 wk (kg), FCA = adjusted feed conversion (point); BMP = breast meat percentage (%); CP = carcass percentage (%); INBMP = indirect BMP measurement (%); INCP = indirect CP measurement (the accuracy of indirect measurement for INBMP and INCP is 100%).

[3]DCM = direct carcass measurements; MICM = male indirect carcass measurements; FICM = female indirect carcass measurements.

[4]Economic response for the breeding goal (ΔG) and genetic response for BW_6, FCA, and BMP.

[5]ΔF = rate of inbreeding.

rect measurements is defined as the genetic correlation (r_g) between direct and indirect carcass traits. When the results of direct and indirect measurements for one trait are equal, the accuracy of the indirect method is considered to be 100%, and, consequently, r_g between direct and indirect carcass traits is unity. Therefore, the genetic parameters of indirect carcass traits (INBMP and INCP) with 100% accuracy of measurement would be the same as the genetic parameters for direct carcass traits (BMP and CP). For indirect methods with accuracy lower than 100%, r_g between direct and indirect carcass traits is determined based on the accuracy of the indirect carcass measurement. The accuracy also influences r_g between indirect carcass traits and other index traits. The following equation was used to incorporate accuracy in the genetic correlations among indirect carcass traits and index traits:

$$r_{g3} = r_{g1} \times r_{g2}$$

where r_{g3} is the genetic correlation between indirect carcass trait and index trait, r_{g1} is the genetic correlation between direct carcass trait and index trait, and r_{g2} is the genetic correlation between direct and indirect carcass traits (= accuracy). Although the accuracy of indirect measurement may influence the heritability of indirect carcass traits, in this simulation, heritability of indirect traits with variable accuracy of measurement was assumed to be the same as direct carcass traits.

The phenotypic and r_g matrices were tested for consistency and bending was used to obtain positive definite matrices. The parameters applied are given in Table 2.

RESULTS

Base Breeding Scheme

The economic response, genetic response per breeding goal trait, and the rate of inbreeding for the base and alternative schemes are given in Table 3. In the base scheme, in which own performance information for carcass traits was not available for selection candidates, the economic response was €0.106, and the genetic responses for BW_6, FCA, and BMP were 0.076 kg, –0.21, and 0.3% per generation, respectively. The estimated rate of inbreeding was 0.963% per generation.

Indirect Carcass Measurement Strategies

The effect of using indirect carcass measurements on birds was investigated in schemes A, B, and C. When indirect carcass measurements were applied to male selection candidates, the response for BMP increased by 28.4% compared with the base breeding scheme, and the rate of inbreeding decreased to 0.852% per generation in scheme A (Table 3). In scheme B, the combination of direct and indirect carcass measurements for male selection candidates provided 39.1% higher response for BMP than the base breeding scheme, and the rate of inbreeding decreased to 0.853% per generation. Application of indirect carcass measurements for male and female selection candidates (scheme C) increased the response for BMP by 66.2% compared with the base breeding scheme, and the predicted rate of inbreeding declined to 0.789% per generation. Genetic responses for BW_6 and FCA hardly changed in the alternative schemes. The increase in BMP was associated with small economic losses due to reduced response in BW_6 and FCA. The losses amounted to 0.84, 1.1, and 1.9% of the economic gain due to increased BMP in schemes A, B, and C, respectively.

Effect of Accuracy of Indirect Carcass Measurements

The effect of accuracy of indirect carcass measurements (100 to 20%) on the genetic response for BMP and the rate of inbreeding were investigated in schemes A, B, and C (Table 4, Figures 2 and 3). When the accuracy of measurements decreased from 100 to 20%, genetic re-

TABLE 4. Effect of indirect measurement accuracy on genetic response of breast meat percentage (BMP) and rate of inbreeding in schemes A, B, and C[1]

Accuracy (%)[2]	Scheme A		Scheme B		Scheme C	
	BMP (%)	*ΔF* (%)[3]	BMP (%)	*ΔF* (%)	BMP (%)	*ΔF* (%)
100	0.380	0.852	0.412	0.853	0.492	0.789
90	0.352	0.916	0.385	0.875	0.460	0.831
80	0.333	0.940	0.375	0.894	0.441	0.859
70	0.308	0.958	0.369	0.910	0.428	0.882
60	0.257	0.973	0.343	0.924	0.409	0.903
50	0.232	0.986	0.329	0.936	0.381	0.922
40	0.201	0.995	0.314	0.946	0.349	0.937
30	0.185	1.002	0.306	0.957	0.324	0.948
20	0.169	1.011	0.276	0.965	0.279	0.959

[1]Base scheme = direct carcass measurements for male relatives; scheme A = indirect carcass measurements on male selection candidates; scheme B = indirect carcass measurements on male selection candidates as well as direct carcass measurements on male relatives; scheme C = indirect carcass measurements for male and female selection candidates as well as direct carcass measurements on male relatives.

[2]Accuracy of indirect carcass measurement.

[3]*ΔF* = rate of inbreeding.

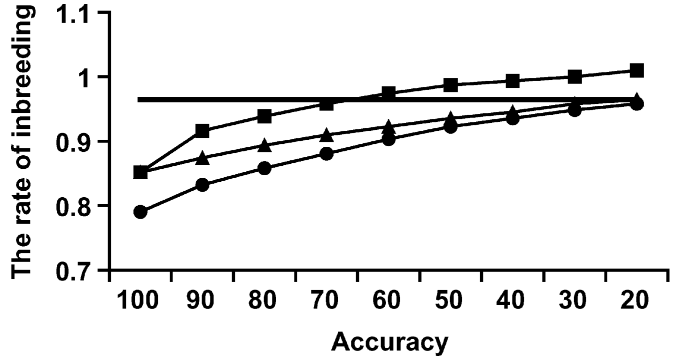

FIGURE 3. The effect of accuracy of indirect carcass measurements on the rate of inbreeding for schemes A (squares), B (triangles), and C (circles) compared with the base scheme (solid line). Base scheme = direct carcass measurements for male relatives; scheme A = indirect carcass measurements on male selection candidates; scheme B = indirect carcass measurements on male selection candidates as well as direct carcass measurements on male relatives; scheme C = indirect carcass measurements for male and female selection candidates as well as direct carcass measurements on male relatives.

sponses for BMP decreased by 56% in scheme A, 33% in scheme B, and 43% in scheme C. The rate of inbreeding increased to 1.01% in scheme A, 0.97% in scheme B, and 0.96% in scheme C, relative to 100% accuracy. Table 4, shows that in the scheme incorporating only indirect carcass measurements (scheme A), the genetic gain for BMP improved with high accuracy indirect methods (higher than 70%). However, schemes with a combination of direct and indirect measurements improved the genetic gain for BMP through low accuracy indirect methods (30%).

DISCUSSION

Different sources of information on carcass performance were included in alternative schemes to increase the genetic gain for BMP. Evaluation of the alternative schemes was based on genetic responses for the breeding goal traits and the rate of inbreeding per generation. The results of the current study indicate that including indirect carcass measurements increase the genetic gain for carcass traits and decrease the rate of inbreeding per generation.

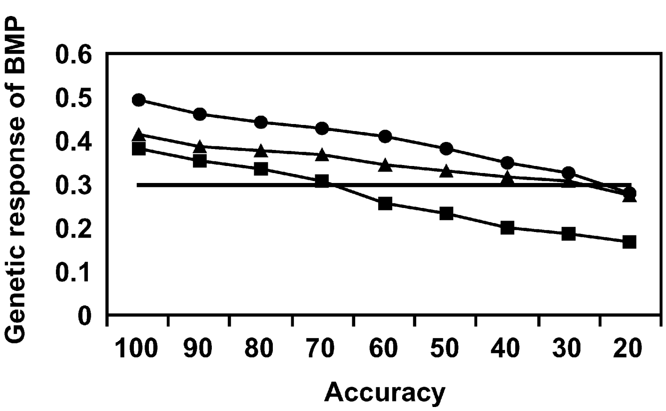

FIGURE 2. The effect of accuracy of indirect carcass measurements on genetic response of breast meat percentage (BMP) in schemes A (squares), B (triangles), and C (circles) compared with the base scheme (solid line). Base scheme = direct carcass measurements for male relatives; scheme A = indirect carcass measurements on male selection candidates; scheme B = indirect carcass measurements on male selection candidates as well as direct carcass measurements on male relatives; scheme C = indirect carcass measurements for male and female selection candidates as well as direct carcass measurements on male relatives.

Genetic Gain

The current study showed that indirect carcass measurements provide own performance information for selection candidates, which increase the accuracy of selection and consequently improve the genetic gain. Indirect carcass methods, such as ultrasonic measures of body composition for genetic evaluation, along with the relationship to carcass traits have been shown to be valuable tools for genetic improvement of carcass traits (Wilson et al., 1998; Reverter et al., 2000; Crews and Kemp, 2001; Devitt and Wilton, 2001).

The accuracy of indirect carcass measurements influences the accuracy of selection with possible consequences for the genetic responses. There are various indirect carcass measurement methods with different accuracy of measurements. Stavrev (1997) found that the accuracy of the ultrasound method (r^2 = 0.6 for muscle weight) was lower than the accuracy of imaging methods. The accuracy of the ultrasound method was affected by the refining algorithms used to estimate the distance to the fat-meat boundary. Scollan et al. (1998) found that the accuracy of MRI for prediction of breast muscle weight (g) from breast muscle volume (cm^3) in broilers is very high (r^2 = 0.99). The results of the present study indicated that indirect carcass methods with higher accuracy of measurement increased the accuracy of selection and consequently improved the genetic responses more than methods with lower accuracy of measurements. Theoretical studies in sheep predict increases in genetic progress that may be as high as 50% (Simm and Dingwall, 1989) or close to 100% (Jopson et al., 1995) through use of CT scanning in combination with ultrasound scanning.

Rate of Inbreeding

SelAction calculates the rate of inbreeding for the Bulmer equilibrium situation accounting for the effect of selection (Rutten et al., 2002). Prediction of the rate of inbreeding is based on the long-term genetic contribution theory (Wray and Thompson, 1990; Woolliams and Bijma, 2000). It has been generally recommended that the rate of inbreeding should be kept below 1% (Morris and Pollott, 1997). High selection intensity and more emphasis on sib information in the index increase the probability of coselection of relatives, which in turn increases the rate of inbreeding. In the current simulation, rate of inbreeding was lower than 1% for all schemes. In the base scheme, selection intensities were chosen close to practical poultry breeding to allow selection for other traits not correlated to the current breeding goal traits, and, consequently, because of low selection intensities, the rate of inbreeding was lower than 1%. In alternative schemes, application of indirect carcass measurements made the own performance of selection candidates available, and less sib information was used in the index. The own performance information reduced the rate of inbreeding in alternative schemes compared with the base scheme, which is favorable for long-term selection.

Quinton et al. (1992) reported that comparisons between breeding schemes should be made at the same level of inbreeding rather than at the same selection intensity due to adverse effects of inbreeding depression. Van Arendonk and Bijma (2003) demonstrated that in the short term, inbreeding and genetic gain have an unfavorable relationship. If schemes are compared that have the same rate of inbreeding, the extra genetic gain for BMP in alternative schemes will be even higher than the base scheme [as has been shown by Pakdel et al. (2005) for ascites-related traits].

Cost

Application of indirect carcass measurements will involve extra costs. However, the current system of raising male birds for carcass tests and dissecting their carcasses might be costly. It is to be expected that the cost of schemes in which direct carcass measurements are replaced by indirect carcass measurements (scheme A) can be lower than in the base scheme because there is no raising and dissection of the carcass of relatives. However, the costs of schemes with direct and indirect carcass measurements (schemes B and C) are likely to be higher than the base scheme especially when imaging methods are used. Whether the cost of indirect carcass measurement methods will be compensated by the additional profit of extra genetic gain remains to be investigated. Costs of using expensive equipment can be reduced by prescreening of candidates or reduction of measurement time (Young et al., 1996). Jopson et al. (1995) showed that in sheep the use of CT scan in a terminal sire breeding program is economically beneficial.

Further Considerations

Early research highlighted the potential of indirect carcass measurements, especially imaging methods (e.g., CT scanning) for the study and evaluation of carcass composition of animals (Vangen and Skjervold, 1981; Young et al., 1996). Apart from indirect carcass evaluation, imaging methods have some other advantages:

1. More intensive data collection through electronic devices such as repeated ultrasound and other imaging methods will provide repeated observation on broilers, which can be analyzed with random regression models; this is now being implemented in beef improvement (Meyer, 1999; Brenoe and Kolstad, 2000; Schenkel et al., 2002).
2. Imaging techniques may enable the user to improve the carcass uniformity, which is important for processing (Basarab et al., 1997).
3. The imaging techniques could offer opportunities to improve the health of the birds (Bartels et al., 1989; Matinez-Lemus et al., 1998; Zhang et al., 1998). Using such information enables the user to have more balance between support and demand tissues for birds, which are selected for higher and more efficient production.

Apart from the cost of imaging techniques, the method of data collection needs to be considered before implementation in practice. For imaging methods animals need to be restrained to minimize movement and ensure animal safety. For sheep, a mild tranquilizer is administered, and animals lie on their backs restrained by broad webbing straps and soft foam pads (Young et al., 1996). For chickens, 3 at the same time are fixed in a stretched position with belts in a specially designed holder and without using anesthetic (Andrassy-Baka et al., 2003). Imaging methods at present require very expensive equipment. However, they offer interesting opportunities for genetic improvement schemes in broilers.

In conclusion, indirect carcass measurements on selection candidates increase the genetic gain for carcass traits and reduce the rate of inbreeding per generation, which is desirable for long-term selection. The accuracy of indirect measurements influences the usefulness of these methods. The combination of direct and indirect carcass measurements is recommended for genetic improvement schemes when indirect measurements with low accuracy are available.

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