Relationship between tissue retention efficiency and production traits in a slow-growing broiler population

J.E. Melo#, J.C. Porteyro Ibarra, A.I. Erias, L.R. Morao, F. Cortés Rondán and M.C. Miquel
Animal Production Department, School of Veterinary Sciences, University of Buenos Aires, Argentina

Abstract

An experiment was conducted using 96 individually caged male broilers between 49 and 77 d of age. One objective was to establish phenotypic relationships between some production traits [feed conversion ratio (FCR), feed consumption, residual feed consumption (RFC), relative weight gain (RWG), weight gain (WG) and live weight (LW)] and "tissue retention efficiency" (TRE) traits in a slow-growing broiler population. The other objective was the characterization of Campero-INTA broilers for TRE traits. Weight and feed consumption were recorded weekly. Forty four broilers were slaughtered at 44 d of age to estimate initial body composition while the remaining birds were slaughtered at 79 d of age. Ether extract and crude protein content of the carcasses were used to estimate TRE traits: Energy retained as protein (ERP), energy retained as fat (ERF), ERP/(ERP+ERF), ERF/(ERP+ERF), protein retention efficiency and lipid-protein ratio. Correlation coefficients between traits were obtained and regression analyses were done for the evaluation of the influence of production traits on TRE traits. The independent variable that best explained ERF was WG (R^2 = 0.49). Inclusion of final LW and RWG raised the R^2 to 0.58 and decreased the error term. The ERP was best explained by RWG (R^2 = 0.37); lipid-protein ratio by final LW (R^2 = 0.49); protein retention efficiency by FCR (R^2 = 0.34) and fraction of retained energy (ERF-ERP/ERP+ERF) by WG (R^2 = 0.29). The TRE traits were not well predicted by the measured production traits. The high phenotypic variability observed in some of the TRE traits suggested a need for further studies on these characteristics.

Keywords: Broiler, tissue retention, efficiency, slow-growing stock
Corresponding author. E-Mail: jemelo@fvet.uba.ar

Introduction

Alternative housing systems including free-range and enriched systems are being developed worldwide in order to satisfy an increasing number of consumers who are prepared to pay higher prices for poultry products when rearing conditions encompasses the welfare of the bird (Remignon & Culioli, 1995). The cost of producing free-range broilers is almost double that of conventional rearing practices. This could be the reason why this type of productive system represents a small percentage of the total poultry production, even in those countries where legislation has been put in place to regulate alternative production systems (Magdelaine, 2004).

Although growing on pasture does not improve the quality of broiler meat, the quality of a product cannot be described only by its nutritional or sensory characteristics. There are also psycho-social properties which are demanded by the consumer (Sauveur, 1997). Sauveur (1997) pointed out that, in France, the main factors required to produce firm and tasty meat from free-range broilers ("Label Rouge") are the age of birds and their genetic background. Considering this, a genotype of bird has been developed by the Argentinean National Institute for Agricultural Technology (INTA). The genetic strain has been developed by crossing slow-growing male and female strains with the retention of properties associated with meat quality (Melo *et al*., 2002; Melo *et al*., 2003). At the University of Buenos Aires, several experiments have been conducted to evaluate slow-growing broilers for production traits and determine what changes are required to produce a broiler efficiently and with an acceptable carcass for this specific market (Melo *et al*., 2002).

Nutritional efficiency should be included as one of the traits in selection objectives of slow-growing broilers due to its economic importance in free-range production (Hubert, 1983). Since fatty tissue deposition is almost four times more costly in energetic terms than lean tissue deposition (Soller & Eitan, 1984), the kind of tissues that are mainly deposited should be considered in association with nutritional efficiency. Selection for decreased body fat content is an unreliable approach of increasing nutritional efficiency, though it does contribute (Geraert *et al.*, 1990; Geraert *et al*., 1993), because feed efficiency and deposition of fat are regulated by different endocrine mechanisms (Pym, 1996). The difference in individual efficiency cannot be explained completely through differences in bodily composition (Jorgensen *et al.*, 1990). Heat production, activity and therefore maintenance energy requirements may be different. Therefore, if progress in nutritional efficiency has to be achieved together with an increase in lean tissue, nutritional efficiency traits that focus on these kind of tissue retentions should be evaluated. It would be advantageous if associations with other traits easier to measure than tissue retention could be established to assist in the selection.

The first objective of this investigation was to characterize slow-growing broilers on their energy and protein metabolism ("tissue retention efficiency" traits), using the most important factors to identify differences between a slow-growing population and standard broiler meat producing birds. The second objective was to establish phenotypic relationships between "tissue retention efficiency" and production traits (feed conversion ratio, feed consumption, residual feed consumption, relative weight gain, weight gain and live weight) to evaluate their use as predictors of the first ones.

Materials and Methods

Campero-INTA broilers were developed by crossing two synthetic populations, a slow-growing male strain and a slow-growing female strain. These two populations were developed at the beginning of the nineteen nineties using mainly closed old Cornish Red, Rhode Island Red and Barred Plymouth Rock strains imported to Argentina in the nineteen sixties. All the mentioned populations were bred at random and not selected for any production traits. White animals were not allowed in the synthetic populations and pedigree information of the male strain was recorded since 2000.

From day-old to 35 d of age 150 Campero-INTA male birds were raised together conventionally on litter-floor pens with feed and water provided *ad libitum*. For 79 days in the summer the birds were grown in an one open-sided poultry house following conventional management recommendations. A lighting program of 23 h light : 1 h dark was used. The temperature was maintained at approximately 35 °C for the first week, and then gradually decreased to 22 °C at 28 d of age. They were individually identified at day one and were weighed weekly. At 35 d of age the birds were allocated to cages in groups of 3 or 4. At 44 d of age, 44 birds taken at random from 44 groups with similar weights, were slaughtered to provide an estimate of their mean body composition. At 49 d of age, 96 broilers were randomly selected, weighed and placed in individual cages with a weighed quantity of feed. For the following four weeks (49 - 77 d of age) the birds and the feed not consumed were weighed weekly to calculate individual feed consumption, weight gain and feed conversion ratio. During the experimental period the mean minimum and maximum ambient temperatures were 22 and 30 °C, respectively. This study was conducted under the guidelines of the Animal Care and Use Committee of the Veterinary School of the University of Buenos Aires.

A commercial starter diet (Iniciador Nutrimentos) was given until the birds were 30 d of age. A mixture (50:50) of the same starter and a commercial finisher diet (Terminador Nutrimentos) was given from 31 to 35 d of age and the finisher diet from days 36 to 79. This included the experimental period. The chemical composition of the commercial starter diet was: 200 g crude protein/kg, 25 g ether extract/kg, 50 g crude fibre/kg, 90 g ash/kg and 900 g dry matter/kg, and that of the finisher diet: 159 g crude protein/kg, 83 g ether extract/kg, 50 g crude fibre/kg, 70 g ash/kg and 920 g dry matter/kg. True metabolisable energy of the finisher diet was calculated to be 14.3 MJ/kg. At 79 d of age all the individually caged birds were slaughtered. The birds were euthanized by cervical dislocation, bled, scalded, plucked and disjoined. All pieces of each broiler, with the exception of feathers but including gut content, were kept in a freezer bag at –10 °C for two months. When a bag was taken out of the freezer the content was minced immediately in order to minimize fat losses during the process. Each chicken was minced at least three times in a 1.5 HP mincer, first through an 8 mm die and then through a 4 mm die until a homogeneous mixture was obtained. Two representative samples (about 100 g each) of each sample were stored in labelled flasks at –10 °C. From the first one, three sub-samples were taken for dry matter, ether extract and crude protein determination. For dry matter determination the samples were dried for four days at 60 °C in a drying oven. Percentage ether extract was determined by Soxhlet extraction (AOAC, 1980). The residual crude protein extraction was determined from the nitrogen value (N x 6.25), using the Kjeldahl technique (AOAC, 1980). The difference between the chemical composition of the birds at 49 days and 79 days was used to estimate the quantity of fat and protein retained per bird.

Results from chemical analyses were used to estimate the tissue retention efficiency (TRE) traits on a dry matter basis. Energy retained as protein (ERP) or fat (ERF) was determined by multiplying the retained quantity 23.68 KJ/g and 39.20 KJ/g, respectively (Brouwer, 1965). The "total retained energy" is the sum of ERP and

ERF and was used to calculate the ratios of partial retention (ERF, ERP/ERF+ERP). Protein retention efficiency was calculated as protein retained over protein consumption. The "fat-protein total ratio" refers to the ratio of fat gain to protein gain (g) between 44 and 79 d of age. The "fat-protein final ratio" is the ratio of fat content to protein content (g) at 79 d of age.

Feed consumption was modelled using weight gain and initial weight as independent variables. Residual feed consumption was calculated as the residual term in this model. Relative weight gain was calculated as the ratio of weight gain to the mean of final and initial body weight. The correlation coefficients between production traits and TRE traits were obtained and regression analyses were done for the evaluation of the influence of production traits on TRE traits. Best-fitted models were determined using the stepwise procedure. GLM and CANCORR procedures of SAS (1985) were used for all analyses.

Results

The means, standard deviations and coefficients of variation obtained for the traits associated to efficiency in tissue retention are presented in Table 1.

Table 1 Means, standard deviation and coefficients of variation for body weight, feed consumption and tissue retention efficiency traits

Trait	N	Means	Standard deviation	Coefficient of variation (%)
Initial body weight (g)	92	1062.9	230.43	21
Final body weight (g)	92	2174.0	377.24	21
Feed consumption (g)	90	3311.0	520.69	15
Energy retained as protein (ERP)*	90	126.98	20.96	16
Energy retained as fat (ERF)*	92	215.97	80.75	37
ERP/ERP+ERF	90	0.39	0.10	26
ERF/ERP+ERF	90	0.61	0.10	17
Protein retention efficiency	88	0.32	0.05	16
Fat-protein total ratio	90	1.03	0.38	37
Fat-protein final ratio	90	1.17	0.24	21

*ERP, ERF: KJ/(BW$^{0.75}$ •day)

The variability of ERF expressed in absolute terms was twice the variability expressed as relative to total retained energy. For the ERP the inverse occurred. Variation of Total Ratios was higher than in Final Ratios.

The ERF showed a higher association with final live weight, weight gain and feed consumption than the ERP, which showed a higher correlation coefficient with initial live weight (Table 2). The ERF and ERP relative to total retained energy (ERP+ERF) showed low to moderate correlations with production traits. Correlation coefficients of protein retention efficiency with residual feed consumption, feed conversion rate and relative weight gain were medium, but low with the rest of the traits. Regression equations were not fitted for fat-protein total ratio, since fat-protein final ratio showed higher correlations with production traits and was easier to measure than total ratio.

The selected TRE traits were modelled as functions of production traits. The equations shown in Table 3 are simple regression models with the independent variables that were statistically significant ($P < 0.05$) and with R^2 values equal to 0.22 or higher. Multiple regression equations with better fits than simple regression models ($P < 0.05$) are also shown.

Including two or more variables instead of one in the model increased the R^2 only for protein retention efficiency and ERF. The best simple regression model for the ERF was the regression on absolute weight gain

(R^2 = 0.49). Inclusion of final live weight and relative weight gain raised R^2 to 0.58 ($P < 0.05$). ERP was better explained by relative weight gain (R^2 = 0.37). Final live weight explained almost half the fat-protein final ratio variability (R^2 = 0.49). Residual feed consumption only explained a low percentage of the variability in TRE (results not shown).

Table 2 Correlation coefficients between tissue retention efficiency traits and growth and feed consumption traits

	FW	IW	WG	FC	FCR	RES	RWG
ERP	0.06	-0.30	0.40	0.15	-0.53	-0.08	0.61
ERF	0.36	-0.03	0.64	0.47	-0.58	0.05	0.57
ERP / ERP+ERF	-0.37	-0.08	-0.54	-0.44	0.47	-0.05	-0.40
ERF / ERP+ERF	0.37	0.08	0.54	0.44	-0.47	0.05	0.40
Protein ret. efficiency	-0.07	-0.30	0.19	-0.08	-0.45	-0.38	0.42
Fat-prot. total ratio	0.38	0.14	0.50	0.44	-0.38	0.05	0.30
Fat-prot. final ratio	0.70	0.63	0.54	0.65	-0.16	0.03	-0.06

FW - final body weight; IW - initial body weight; WG - absolute weight gain; FC - feed consumption; FCR - feed conversion rate; RES - residual feed consumption; RWG - relative weight gain; ERP - energy retained as protein; ERF - energy retained as fat

Table 3 Significant ($P < 0.05$) regression models and independent variables (X) for modelling tissue retention efficiency traits

Y	X	RSD	R^2
ERP	FCR (-)	17	0.28
ERP	RWG	16	0.37
ERF	WG	58	0.46
ERF	FC	69	0.26
ERF	FCR (-)	63	0.36
ERF	RWG	66	0.32
ERF	FW, WG, RWG (-)	52	0.58
ERP / ERP+ERF	WG (-)	0.08	0.29
ERF / ERP+ERF	WG	0.08	0.29
Protein ret. efficiency	WG, FC (-)	0.04	0.34
Fat-prot. final ratio	FW	0.17	0.49
Fat- prot. final ratio	IW	0.19	0.39
Fat- prot. final ratio	WG	0.21	0.29
Fat- prot. final ratio	FC	0.19	0.42

FW - final body weight; IW - initial body weight; WG - absolute weight gain; FC - feed consumption; FCR - feed conversion rate; RES - residual feed consumption; RWG - relative weight gain; ERP - energy retained as protein; ERF - energy retained as fat; RSD - residual standard deviation

Discussion

The values of ERP and ERF for the birds in this study were intermediate to that obtained by Geraert *et al*. (1988) and Geraert *et al*. (1993) for fat and lean lines, and lower than those reported by Jorgensen *et al*. (1990) for lines selected on feed conversion ratio and weight gain. Protein retention efficiency was lower than that reported by Geraert *et al*. (1988) and Geraert *et al*. (1990) for the fat and lean lines. Nonetheless, Geraert *et al*. (1993) obtained lower values for protein retention efficiency in their fat line than that of the Campero-INTA subjected to a high temperature (32 °C) and at an older age (63 days). These results are in agreement with Cahaner & Leenstra (1992), who obtained lower values to those presented here, also under high temperature conditions. This would indicate intermediate results between leaner and fat lines for the genotype in study, as could be expected from a population with a low selection level, such as the Campero-INTA. The fat-protein ratio in the present study is similar to that reported by Hancock *et al.* (1995) for 11-week old males from six commercial populations (1.17) of the same age as in the present study. Geraert *et al.* (1993), working with birds slaughtered at nine weeks, reported fat-protein ratios of 0.75 for the lean stock and 1.33 for the fat stock; values that were both exceeded by some Campero-INTA birds. This indicates high phenotypic variability for the trait in this genotype.

In the present study the ERP/ERP+ERF and ERF/ERP+ERF ratios were almost independent of live weight at 49 and 79 days. However, a higher absolute weight gain was found for the animals showing the highest ERF/ERP+ERF values. The average weight gain of the 20 animals with the higher ERF/ERP+ERF and the 20 animals with higher ERP/ERP+ERF between 49 and 79 d of age were due to differences in fat gain. Differences among birds in total weight gain were also due to differences in fat gain. Contrary to this, Geraert *et al.* (1993) found that their lean line was heavier than the fat line at nine weeks of age.

Broilers that retained a lower fatty fraction (ERF/ERP+ERF) showed lower feed consumption, according to the obtained correlation coefficients between both traits, in agreement with Geraert *et al.* (1988), Geraert *et al*. (1990) and Geraert *et al*. (1993). Differences in feed consumption seem to be mainly due to live weight and weight gain because their affect diminished when feed consumption was corrected for both variables.

Lean and fat lines used by Geraert *et al.* (1988), Geraert *et al*. (1990) and Geraert *et al*. (1993) differed in protein retention efficiency ($P < 0.05$) and in feed conversion ratio as a result of differences in feed consumption and weight gain (Geraert *et al.*, 1993) or just feed consumption (Geraert *et al.*, 1990). This is consistent with the phenotypic correlations estimated in the present study. Differences among birds in protein retention efficiency could indicate differences in protein deposition rate, because of the differences in efficiency of lean and fat tissue deposition (Soller & Eitan, 1984). This is also sustained by the percentage of protein efficiency variation explained by the corporal protein ($R^2 = 0.42$), according to a simple regression model fitted ($P < 0.05$). Difference already existed in bodily chemical composition when measurements on protein efficiency started, and it was maintained until 79 d of age, independently of live weight, since at 49 days 45 g of protein were retained for each 100 g retained for the 20 birds with higher protein efficiency, and 40 g for the 20 chickens with lower protein efficiency. This difference was maintained until 79 d of age.

Two points can be highlighted: The first is that differences in weight gain were mainly due to differences in fat gain. This implies that if weight gain is selected, a leanness measurement should be included in the breeding objective in order to avoid increased fat deposition. The second point is that protein efficiency was higher in animals with both higher weight gains and low feed consumption. Since results on growth and consumption patterns of other broiler populations housed in cages were the same as in floor housing (Sorensen, 1989; Jain, 1996), the obtained results could have direct applications to free-range broiler production.

Conclusions

The results of this experiment indicate that production traits have a low relationship with TRE traits. The use of production traits as predictors of TRE traits is, therefore, not recommended. However, only through knowledge of the relevant genetic parameters can the response to selection be determined. The observed high phenotypic variability in some of the TRE traits emphasized the need for further studies on these traits to be used in selection programmes.

Acknowledgements

J.E. Melo holds a scholarship from FOMEC. This research was supported by the VE-059 UBACyT Project and the PICT-4693 FONCyT Project.

References

AOAC, 1980. Official Methods of Analysis (13th ed.). Association of Official Analytical Chemists, Washington, D.C., USA.

Brouwer, E., 1965. Report of subcommittee on constants and factors. In: Third Symp. Energy Metabolism. Ed. Blaxter, K., European Association of Animal Production. pp. 441-443.

Cahaner, A. & Leenstra, F., 1992. Effects of high temperature on growth and efficiency of male and female broilers from lines selected for high weight gain, favourable feed conversion, and high or low fat content. Poult. Sci. 71, 1237-1250.

Geraert, P., MacLeod, M. & Leclercq, B., 1988. Energy metabolism in genetically fat and lean chickens: diet and cold-induced thermogenesis. J. Nutr. 118, 1232-1219.

Geraert, P., MacLeod, M., Larbier, M. & Leclercq, B., 1990. Nitrogen metabolism in genetically fat and lean chickens. Poult. Sci. 69, 1911-1921.

Geraert, P., Guillaumin, S. & Leclercq, B., 1993. Are genetically lean broilers more resistant to hot climate? Br. Poult. Sci. 34, 643-653.

Hancock, C., Bradford, G., Emmans, G. & Gous, R.M., 1995. The evaluation of the growth parameters of six strains of commercial broiler chickens. Br. Poult. Sci. 36, 247-264.

Hubert, G., 1983. Selection of specialized strains to obtain a slow growing broiler. Proc. 6th Eur. Symp. on Poult. Meat, Ploufragan, France. pp. 13-20.

Jain, G., 1996. Comparative evaluation of selection of broilers on the basis of growth rate versus feed efficiency. Proc. XX World's Poult. Congr., New Delhi, India. pp. 479-488.

Jorgensen, H., Sorensen, P. & Eggum, B., 1990. Protein and energy metabolism in broiler chickens selected for either body weight gain or feed utilization. Br. Poult. Sci. 31, 517-524.

Magdelaine, P., 2004. Development in biological poultry meat production in EU. Proc. XXII World's Poult. Congr., Istanbul, Turkey. p. 928.

Melo, J., Iglesias, G., Soria, L., Mallo, G., Huguet, M., Canet, Z., Marrube, G., Pinto, G., Rozen, F., Mirande, S. & Miquel, M.C., 2002. Selection criteria for free range broilers including quantitative traits and molecular markers. Proc. VII World Congr. on Genetics Applied to Livestock Prod., Montpellier, France. p. 87.

Melo, J.E., Motter, M.M., Morao, L.R., Huguet, M., Canet, Z. & Miquel, M.C., 2003. Use of in-vivo measurements to estimate breast and abdominal fat content of a free-range broiler strain. Anim. Sci. 77, 23-31.

Pym, R., 1996. Selection for feed efficiency and increased lean tissue growth rate in meat chickens. Proc. XX World's Poult. Congr., New Delhi, India. pp. 469-478.

Remignon, H. & Culioli, J., 1995. Meat quality traits of French "Label" chicken. Proc. 12th Eur. Symp. on Poult. Meat, Zaragoza, Spain. pp. 145-450.

SAS, 1985. Statistical Analysis Systems user's gGuide (5th ed.). SAS Institute Inc., Cary, North Carolina, USA.

Sauveur, B., 1997. Criteria and factors of the quality of French Label Rouge chickens. INRA Prod. Anim. 10, 219-226.

Soller, M. & Eitan, Y., 1984. Why does selection for live weight gain increase fat deposition? A model. World's Poult. Sci. J. 40, 5-9.

Sorensen, P., 1989. Interaction between genotype and management factors in broilers. In: Genotype x Environment Interactions in Poultry Production. Ed. Merat, P., Jouy-en-Josas, INRA. pp. 67-82.