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Growth Performance, Carcass Characteristics and Meat Quality of Griller-Type Broilers of Four Genetic Lines

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Carcass yield, genetics, griller-type, growth performance, meat quality.

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ABSTRACT

Griller-type chickens are broilers slaughtered between27and 29 days old weighing 1.3 to 1.5 kg and sold as a whole carcasses. The aim of the present study was to evaluate the growth performance, carcass traits, and meat quality of female broilers of four genetic lines reared for the production of griller-type chickens. A total of 960 broiler chicks was allotted in a randomized block design with four treatments and eight replicates of 30 birds per experimental plot. Each experimental treatment consisted of four different commercial lines, identified as A, B, C and D. The analyzed parameters were weight gain, feed intake, feed conversion ratio, livability, production efficiency index, carcass and cut yields, and meat quality according to breast meat color (L*, a*, b*), water-holding capacity (WHC), cooking losses, and shear force. Weight gain, feed intake, feed conversion ratio, and livability were different ($p<0.05$) among the lines; however, no differences were observed for the production efficiency index. Results show that lines presented similar performance; however, lines A, B, and C had a better carcass and breast yield, and line A, the best meat quality. Therefore, line A would be the most suitable for the production of griller-type chickens.

INTRODUCTION

Brazil is the world's second largest producer of chicken meat, with an annual production of 13,146 million tons, ranking as the world's largest exporter, with approximately 4,304 million tons of chicken meat marketed in 2015 (ABPA, 2016). One the exported products is whole carcass, known as a griller. A griller is a whole frozen carcass commercially known as *griller-type chicken*, obtained from 27- to 29-d-old broilers with 1.3 to 1.5 kg live weight and feed conversion ratio of 1.5 kg of feed per 1 kg of meat (Olivo, 2006).

The production of griller-type chickens is based on high housing density (15-17 birds/m^2), with the objective of reducing costs and maximizing income to the farmer (Arruda, 2013). In Brazil, the production practices have significantly improved during the last decades due to technological development in genetics, nutrition, management, health, and rearing environment. Havenstein *et al.* (2003) reported that genetic selection accounts for 85% of the improvement in the performance of broiler chickens. According to Avila *et al.* (1993), Souza *et al.* (1994), Stringhini *et al.* (2003) and Janisch *et al.* (2011), the objectives of studies evaluating broiler genetics are to not only improve their performance, but also carcass and parts traits.

Such studies are essential due to the rapid evolution of genetic improvement, which has allowed the development of the poultry industry (Lara *et al.* 2008). However, there are few studies investigating the production of griller-type chickens. The objective of this study was to evaluate the performance, carcass traits, and meat quality of females of different genetic lines for the production of griller-type chicken.

MATERIAL AND METHODS

Birds and Treatments

A total of 960 one-day-old female chicks of four genetic lines were reared for 28 days. The birds were housed in a conventional poultry house, and were distributed into 32 floor pens measuring 2.10 m^2 each. Brooding and curtain management for the control of house temperature were performed as needed. The lighting program applied was 24 hours of light until the birds were 14 days old and then 16 hours of light until the end of the experiment. During the experiment, the average recorded temperature and relative humidity were 21.52 °C and 65%, respectively.

The broilers received water and feed *ad libitum* throughout the experimental period. The diets were isonutritive and isoenergetic, and formulated according to Rostagno *et al.* (2011). The ingredient and calculated nutrient composition of the feeds are shown in Table 1.

Broilers were allotted in a randomized block design with four treatments of eight replicates of 30 birds each (experimental unit). The experimental treatments consisted of different commercial lines of female chickens, which were identified in the hatchery as lines A, B, C, and D, corresponding to Cobb 500, Hubbard Flex, and Ross AP91 and AP95. Four samples of thirty birds were randomly selected in the hatcheries and weighed. Average initial weight body weights were determined as 45.65±0.51, 45.91±0.38, 48.33±0.66, and 45.62±0.54 g for lines A, B, C, and D, respectively.

Live performance

The evaluated performance parameters were feed intake, weight gain, feed conversion ratio, livability, and production efficiency index (PEI), which was calculated using the following formula: PEI = (daily weight gain (kg) ×livability /feed conversion ratio)×100, according to the method described by Lorençon *et al.* (2007).

Carcass traits

On day 29, four birds per experimental unit, with body weight close to average of the experimental unit, were selected and submitted to fasting for eight hours. Birds were then individually weighed on the slaughter platform. Birds were electrically stunned in water bath equipment (Model FX 2.0, Fluxo, Chapecó, Brazil), where they were exposed for ten seconds to an electrical current (800-Hz frequency and42-V voltage), and then bled, scalded, plucked, eviscerated, and cut up to determine the carcass and parts yields.

Carcass yield was calculated as carcass weight without the head, feet and neck determined immediately

Table 1 – Diet composition, nutritional and metabolizable energy (ME) values of pre-starter (1-7 days), starter (8-17 days) and grower (18-28 days) diets.

Ingredients (%)	Rearing phase (days)		
	1 – 7	8 – 17	18 – 28
Ground corn, 8,0% CP	59.91	62.98	66.52
Soybean meal, 46% CP	30.09	28.35	22.69
Meat meal, 42% CP	3.87	3.30	2.03
Feather meal	-	-	2.00
Offal meal, 16% EE	-	-	1.67
Soybean oil	1.57	1.89	2.76
Limestone	0.86	0.74	0.62
Sodium bicarbonate	0.18	0.13	0.10
Salt	0.32	0.30	0.31
Hemoglobin	1.00	1.00	-
Spray-dried plasma	0.80	-	-
DL-methionine	0.31	0.30	0.27
L-lysine HCl (50%)	0.33	0.32	0.50
L-threonine (98%)	0.14	0.12	0.11
Vit-Min premix[1]	0.13	0.12	0.10
Choline chloride (75%)	0.09	0.10	0.07
Additives[2]	0.40	0.35	0.26
TOTAL	100.00	100.00	100.00
Calculated values			
ME (kcal/kg)	3.050	3.100	3.220
Crude Protein (%)	22.46	21.00	19.70
Calcium (%)	1.02	0.90	0.82
Available phosphorus (%)	0.39	0.34	0.31
Sodium (%)	0.24	0.20	0.19
Lysine (%)	1.32	1.21	1.12
Methionine+cystine (%)	0.95	0.90	0.85
Methionine (%)	0.61	0.58	0.53

[1] Composition/kg of product. Pre-starter: vitamin A: 10,530 IU; vitamin D_3: 2600 IU; vitamin E: 31.2 mg; vitamin K_3: 2.34 mg; vitamin B_1: 2.82 mg; vitamin B_2: 7.2 mg; vitamin B_6: 4.26 mg; vitamin B_{12}: 0.015 mg; Niacin: 40.95 mg; Pantothenic acid: 14.04 mg; Folic acid: 0.936 mg; Biotin: 0.0702 mg; Fe: 52.65 mg; Cu: 11.7 mg; Mn: 81.9 mg; Zn: 81.9 mg; I: 1.17 mg; Se: 0.351 mg; Antioxidant: 117 mg; Starter: vitamin A: 9720 IU; vitamin D_3: 2400 IU; vitamin E: 28.8 mg; vitamin K_3: 2.16 mg; vitamin B_1: 2.61 mg; vitamin B_2: 6.48 mg; vitamin B_6: 3.93 mg; vitamin B_{12}: 0.014 mg; Niacin: 37.8 mg; Pantothenic acid: 12.96 mg; Folic acid: 0.864 mg; Biotin: 0.0648 mg; Fe: 48.6 mg; Cu: 10.8 mg; Mn: 75.6 mg; Zn: 75.6 mg; I: 1.08 mg; Se: 0.324 mg; Antioxidant: 108 mg; Grower: vitamin A: 8100 IU; vitamin D_3: 2000 IU; vitamin E: 24 mg; vitamin K_3: 1.80 mg; vitamin B_1: 2.17 mg; vitamin B_2: 5.4 mg; vitamin B_6: 3.28 mg; vitamin B_{12}: 0.0117 mg; Niacin: 31.5 mg; Pantothenic acid: 10.8 mg; Folic acid: 0.720 mg; Biotin: 0.054 mg; Fe: 40.5 mg; Cu: 9 mg; Mn: 63 mg; Zn: 63 mg; I: 0.9 mg; Se: 0.27 mg; Antioxidant: 90 mg. [2]Neoacid[â] (1 kg/ton); Mycofix[â] (1.5 kg/ton); Salinomycin (0.55 kg/ton); AVIAX[â] (0.5 kg/ton); Betaine 95% HCl (0.4 kg/ton); Poultry Grow[â] (0.125 kg/ton); prebiotic (0.4 kg/ton); Optiphós[â] (0.063 kg/ton); Rovabio Excel AP[â] (0.05 kg/ton).

after evisceration relative to live weight. Breast, legs (thigh and drumstick), back, and wing yields were calculated as their weight relative to eviscerated carcass weight, according to Mendes (2001).

Abdominal fat yield was determined as its weigh relative to eviscerated carcass weight. Abdominal fat was defined as the adipose tissue present around the vent, bursa, and adjacent abdominal muscles, according to Smith (1993).

Meat Quality

After the determination of the carcass and yield cuts, breast (*pectoralis major*) meat samples were removed from carcasses approximately 20 min after slaughter, placed in labeled plastic bags, sealed, chilled in ice bath, and stored at 4 °C for 24 hours, after which they were analyzed for following meat quality traits: pH, color, water-holding capacity, cooking loss and shear force.

The pH was measured by inserting the electrodes into the meat samples using a contact pH meter system (Model 205, Testo AG, Lenzkirch, Germany). The color measurements were taken on the dorsal surface of the samples using a Minolta chroma meter (Model CR10, Minolta, Osaka, Japan). The L*, a*, and b* measurements were evaluated according to the CIELAB system, where L* corresponds to lightness, a* to redness (between green and red), and b* to yellowness (between blue and yellow). Average L*, a*, and b* values were calculated from three readings in different positions.

The water-holding capacity was determined according to the method described by Hamm (1960). Twenty-four hours *post-mortem*, samples were collected from the cranial side of the breast fillets and cut into 2.0-g(±0.10) cubes. The samples were analyzed in duplicate. They were first carefully placed between two filter papers and then left under a 10-kg weight for 5 min. The samples were then weighed and WHC was determined according the following equation:

$$WHC(\%) = 100 - \left[\left(\frac{W_i - W_f}{W_i}\right) \times 100\right]$$

where Wi and Wf are the initial and final sample weights.

Cooking loss (CL) was determined according to the methodology proposed by Cason *et al.* (1997). Raw breast meat samples were weighed (± 90 g), packaged, and steam-cooked in water bath at 85 °C for 30 minutes, until internal end-point temperature of 75 to 80 °C. Samples then left to cool until reaching room temperature and weighed. Cooking loss was calculated as: CL (%) = 100 × (1– cooked weight/fresh weight).

Shearforce was determined using the CT3 Texture Analyzer (Brookfield, Germany) coupled to a Warner-Bratzler probe. The cooked breast muscle samples used for the determination of cooking losses were tested. The samples were cut into 1.5-cm wide and 1.0-cm deep in depth slices and then placed perpendicularly to the Warner-Bratzler blade. The maximum force required to cut the slices was determined (kgf).

Statistical Analysis

The data were submitted to analysis of variance, and subsequently, the means were compared by Tukey's test at a 5% significance level.

RESULTS AND DISCUSSION

Performance

The live performance results (Table 2) showed that line C presented the highest (p<0.05) weight gain, whereas lines A and B were not different from the other treatments, while line D birds were the lightest. Feed intake was the lowest in line D (p<0.01). Based on these results, the chickens of line D presented less weight gain and lower feed intake, and therefore, better feed conversion than the other lines (p<0.01).

Table 2 – Weight gain (WG), feed intake (FI), feed conversion ratio (FCR), livability (L) and production efficiency index (PEI) of females of different genetic lines reared from1 to 28 days of age (griller).

Lines	WG (g)	FI (g)	FCR	L (%)	PEI
A	1425ab	2060a	1.45b	96.67b	340.22a
B	1419ab	2070a	1.45b	99.58a	350.79a
C	1444a	2102a	1.44b	98.34ab	349.06a
D	1414b	2008b	1.42a	99.17ab	352.70a
P –value	0.044	0.001	0.005	0.025	0.059
CV (%)	1.46	1.58	0.98	1.90	2.63

[a, b] Means followed by different letters in the same column differ significantly by Tukey's test (p< 0.05).

Livability was different (p<0.05) between lines A and B, which presented the highest values. The production efficiency index was not different among the lines (p>0.05).

The differences (p<0.05) observed in feed intake, weight gain, and feed conversion ratio can be ascribed to genetic characteristics, as each line is selected for different growth patterns (Soares *et al.* 1991; Bilgili *et al.* 1992). In addition to the genetic potential of each line, the initial weight of the birds can also be regarded as responsible for the performance differences (Leandro *et al.* 2006), as heavier day-old chicks have better overall performance. According to Lara *et al.* (2005), each additional gram of initial body weight results in 13 additional grams more at slaughter age. Despite the differences in feed intake, weight gain, feed conversion and livability, no differences (p>0.05) were determined for the production efficiency index, the factor that is used to pay the producer.

Carcass Yield

Carcass yield, and breast, leg, back, and wing yields were different (p<0.05) among the evaluated lines (Table 3). Line A produced higher carcass yield than lines C and D, whereas line B was not different (p<0.01) from lines A and C.

Higher breast yield values were obtained in lines A, B, and C (p<0.01) compared with line D, which presented higher (p<0.01) wings and leg yields than the other genetic groups. The highest back yield was obtained inline D birds (p<0.05), while no differences were detected in lines B and C (p>0.05). Abdominal fat yield was not different (p>0.05) among the lines.

These results indicate that line D birds presented the lowest weight gain (p<0.05) as well as the lowest carcass and breast yields. In addition, line D chickens (line D) presented the lowest breast yield (p<0.01) and the highest leg, back and wings yield. According to Le Bihan-Duval *et al.* (1998), there is a positive correlation (0.76) between body weight and breast meat yield, indicating that heavier chickens produce greater breast yield. According to Rance *et al.* (2002), there is a negative correlation (-0.65) between breast yield and leg yield. Furthermore, there is a mathematical relationship in parts yield: the lower the breast yield, the higher the yield of other parts, such as that of legs, back and wings.

Abdominal fat yield was not different among the lines because the chickens were slaughtered at 29 days of age, when fat deposition is low. According to Holanda *et al.* (2009), fat deposition rate increases by the end of the rearing phase when broilers are slaughtered with 42 days of age.

Meat Quality

The breast meat of different lines of griller-type chickens showed significant differences (p<0.01) in L*and b* values, and water-holding capacity, whereas pH, a* values, cooking loss, and shear force were not different among the evaluated lines (p>0.05). The highest breast meat lightness value was obtained in line C, which was higher than 53, indicating pale meat (Qiao *et al.* 2001; Soares *et al.* 2002). The breast of line-A birds presented the lowest L* values, whereas lines B and D were different from the other treatments. Yellow color intensity was highest in line C and lowest in lines A and B, whereas line D did not differ from the other treatments. The breast meat of lines A and D presented higher water-holding capacity compared with lines B and C.

Meat color may vary according to the xanthophyll types and levels present in the diet and to genetics (Oda *et al.* 2003). Therefore, as all birds in the present experiment were fed under the same diet, the meat color results can be attributed to genetics.

According to Dransfield & Sosnicki (1999), the selection for high growth rates of modern genetic lines causes structural and metabolic changes in the muscles, increasing the diameter of the muscle fibers and the proportion of glycolytic fibers. These fibers, under stress

Table 3 – Carcass yield (CY), breast yield (BRY), thigh + drumstick yield (TD), back yield (BY), wings yield (WY) and abdominal fat yield (AFY) of griller-type chickens from different lines[1].

Lines	CY (%)	BRY (%)	TD (%)	BY (%)	WY (%)	AFY (%)
A	72.94a	38.26a	29.50b	18.97b	10.70b	2.60a
B	72.67ab	37.98a	29.54b	19.13ab	10.74b	2.61a
C	72.14bc	37.48a	29.90b	19.25ab	10.70b	2.69a
D	71.46c	35.22b	31.33a	19.79a	11.28a	2.38a
P–value	<0.001	<0.001	<0.001	0.012	<0.001	0.189
CV (%)	1.56	4.14	3.5	5.37	4.01	23.27

[a, b, c] Means followed by different letters in the same column differ significantly by Tukey's test (p< 0.05).

[1]n = 40 fillets per treatment.

Table 4 – Values of pH, L*(lightness), a* (redness), b* (yellowness), water-holding capacity (WHC), cooking losses (CL) and shear force (SF) of breasts of different griller-type chicken lines[1].

Lines	pH	L*	a*	b*	WHC(%)	CL(%)	SF(kgf)
A	5.82a	51.96b	1.55a	14.25b	66.89a	24.25a	2.67a
B	5.83a	52.96ab	1.54a	14.02b	64.23b	24.08a	2.38a
C	5.85a	54.69a	1.49a	15.72a	64.36b	24.18a	2.37a
D	5.85a	53.49ab	1.32a	14.78ab	66.81a	23.12a	2.35a
P – value	0.423	0.002	0.664	0.002	0.002	0.467	0.732
CV (%)	1.72	5.34	54.96	12.39	3.57	9.57	38.16

[a, b] Means followed by different letters in the same column differ significantly by Tukey's test ($p < 0.05$).

[1]n = 40 fillets per treatment.

and high-energy demand conditions, increase their metabolic rate, quickly reducing the pH due to the high production of lactic acid, which cannot be removed *postmortem*. Although there were no differences in pH, which is important for meat quality, the breast meat of line-C birds, in addition of presenting the highest lightness value, also showed the highest yellowness value and lower water-holding capacity. According to Bainy (2011), there is a positive correlation (0.20) between meat lightness and yellowness, and Castro *et al.* (2008) reported negative correlations between water-holding capacity and lightness (-0.62) and yellowness (-0.24). When there is a higher degree of protein denaturation, less light is transmitted through the muscle surface and more light is dispersed, leading to a pale meat color (Olivo *et al.* 2001). In addition, as a result of greater protein denaturation, there is more damage in the muscle fibers, consequently reducing its capacity to retain water and negatively affecting their functional properties.

Despite the detected differences in breast meat lightness and water-holding capacity, these factors did not influence shear force.

CONCLUSIONS

It is concluded that all lines presented similar production efficiency index; however, lines A, B and C showed better carcass and breast yield, and line A produced the best meat quality. Therefore, these results indicate that line A is the most suitable for the production of griller-type chickens.

REFERENCES

Arruda JNT. Effect of population density on live performance, animal welfare, performance and carcass quality in broilers of different commercial strains [dissertation]. Dois Vizinhos (PR): Universidade Tecnológica Federal do Paraná; 2013.

Associação Brasileira de Proteína Animal - ABPA. Relatório Anual da Avicultura 2016. [cited 2017 Mar 13]. Available from: http://abpa-br.com.br/storage/files/abpa_relatorio_anual_2016_ingles_web_versao_para_site_abpa_bloqueado.pdf.

Avila VS, Ledur MC, Barioni Junior M, Schmidt GS, and Costa CN. Performance and carcass quality in commercial lines of broilers. Pesquisa Agropecuária Brasileira 1993:28(6):649-656.

Bainy AM. Parâmetros genéticos de caracteristicas de carcaça e de qualidade da carne de aves oriundas de cruzamento recíproco [dissertation]. Jaboticabal (SP): Universidade Estadual Paulista; 2011.

Bilgili SF, Moran Jr ET, Acar N. Strain-cross response of heavy male broilers to dietary lysine in the finisher feed: Live performance and further-processing yields. Poultry Science 1992;71(5):850-858.

Cason JA, Lyon CE, Papa CM. Effect of muscle opposition during rigor on development in broiler breast meat tenderness. Poultry Science 1997;76(5):725-787.

Castro JBJ, Castilho JCC, Ortega EMM,Pedreira MS. Feed withdrawal periods in the quality of broilers meat raised in the conventional system. Ciência Rural 2008;38(2):470-476.

Dransfield E, Sosnicki AA. Relationship between muscle growth and poultry meat quality. Poultry Science 1999;78(5):743-746.

Hamm R. Biochemistry of meat hydration. Advances in Feed Research 1960;10:355-463.

Havenstein GB, Ferket PR ,Qureshi MA. Growth, livability, and feed conversion of 1957 vs 2001 broilers when fed representative 1957 and 2001 broiler diets. Poultry Science 2003;82(10):1500-1508.

Holanda MAC, Ludke MCMM, Ludke JV, Holanda MCR, Rabello CBV, Dutra Jr WM, Vigoderis RB,CostaAAG. Performance and carcass characteristics of broiler chicken receiving diets with hydrolyzed feather meal. Revista Brasileira de Saúde e Produção Animal 2009;10(3):696-707.

Janisch S, Krischeck C, Wicke M. Color values and other meat quality characteristics of breast muscles collected from 3 broiler genetic lines slaughtered at 2 ages. Poultry Science 2011;90(8):1774-1781.

Lara LJC, Baião NC, Cançado SV, Teixeira JL, Lopez CAA, Duarte FD, et al. Effect of chick weight on performance and carcass yield of broilers. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2005;57(6):799-804.

Lara LJC, Baião NC, Rocha JSR, Lana AMQ, Cançado SV, Fontes DO, et al. Influence of physical form of ration and line on the performance and yield of broiler cuts. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2008;60(4):970-978.

Leandro NSM, Cunha WCP, Stringhini JH, Cruz CP, Café MB Matos MS. Effect of broiler chicken initial weight on performance, carcass yield and economic viablity. Revista Brasileira de Zootecnia2006; 35(6): 2314-2321.

Le Bihan-Duval E, Mignon-Gastreau, S, Millet N, Beaumont C. Genetic analysis of a selection experiment on increase body weight and breast muscle weightas well as on limited abdominal fat weight. British Poultry Science 1998;39(3):346-353.

Lorençon L, NunesRV, Pozza PC, Pozza MSS, Applet MD, Silva WTM. Utilization of growth promoter for broiler chickens in mashed and pellets diets. Acta Scientiarum Animal Science 2007;29(2):151-158.

Mendes AA. Rendimento e qualidade da carcaça em frangos de corte. Anais da Conferência Apinco de Ciência e Tecnologia Avícolas; 2001; Campinas, São Paulo. Brasil.

Oda SHI, Schneider JP, Soares AL, Barbosa DML, Ida EI, Olivo R, Shimokomaki M. Detecção de cor de filés em peito de frango. Revista Nacional da Carne 2003;28:30-34.

Olivo R, Guarnieri PD, Shimokomaki M. Fatores que influenciam na cor de filés de peito de frango. Revista Nacional da Carne 2001;25(289):44-49.

Olivo R. O mundo do frango: cadeia produtiva da carne de frango. São Paulo: Varela; 2006.

Qiao M, Fletcher DL, Smith DP, Northcutt JK. The effect of broiler breast meat color on pH, water-holding capacity, and emulsification capacity. Poultry Science 2001;80(5):676-680.

Rance KA, McEntee GM, McDevitt RM. Genetic and phenotypic relationships between and within support and demand tissues in a single line of broiler chicken. British Poultry Science 2002;43(4):518-527.

Rostagno HS, Albino LFT, Donzele JL, Gomes PC, Oliveira RF, Lopes DC, et al. Brazilian tables for poultry and swine: composition of feedstuffs and nutritional requirements. 3rd ed. Viçosa: UFV; 2011.

Smith MO. Parts yield of broilers reared under cycling high temperatures. Poultry Science 1993;72(6): 1146-1150.

Soares PR, Fonseca JB, Silva MA, Graças AS, Rostagno HS, Silva ACA. Performance of four commercial broiler strains raised under different stocking density. Revista Brasileira de Zootecnia 1991;20(1):74-79.

Soares AL, LaraJAF, Ida EI, Guarnieri PD, Olivo R, Shimokomaki M. Variation in the colour of Brazilian broiler breast fillet. Proceedings of 48th International Congress of Meat Science and Technology; 2002 Aug 25-30; Rome. Italy. p. 540-541.

Souza PA, Souza HBA, Campos FP, BrognoniE. Performance and carcass characteristics of different commercial broiler chicken strains. Revista Brasileira de Zootecnia 1994;23(5):782-791.

Stringhini JH, Laboissiére M, Muramatsu K, Leandro NSM, Café MB. Performance and carcass yield of four broiler strains raised in Goiás, Brazil. Revista Brasileira de Zootecnia 2003;32(1):183-190.