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Comparison of Free Range Broiler Chicken Strains Raised in Confined or Semi-Confined Systems¹

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■ Keywords

Growth curve, ISA Label, meat quality, Paraíso Pedrês, raising system

ABSTRACT

The present study was carried out to compare the growth curve, performance and carcass yield of two broiler strains, Paraíso Pedrês (PP) and ISA Label (ISA), raised in confined or semi-confined systems. It was used a completely randomized design with five replicates, consisting of 20 and 29 birds in semi-confined and confined systems, respectively. Semi-confined birds had free access to pasture at 28 days of age. Performance data were recorded weekly by building growth curves as well as calculating the growth rate. After reaching the recommended body weight (2.5 kg), male birds were slaughtered for physicochemical analysis of carcass, parts and organs. Semi-confined PP and ISA birds showed higher growth potential, higher weight gain, lower feed intake and better feed-to-gain ratio than confined birds. No interactions were observed for carcass yield and meat quality characteristics. Males presented higher yields of feet, drumstick, thigh, drumstick + thigh, and heart, while females presented higher breast and abdominal fat yield. Breast meat from ISA Label birds was more yellowish than from PP, whereas less soft meat was observed in semi-confined birds.

INTRODUCTION

The demand of consumers for different poultry products has influenced changes in commercial poultry husbandry (Gessulli, 1999; Vercoe *et al.*, 2000), and lead to increased development (Verbeke & Viane, 2000). Society segments have shown great interest in production systems, animal welfare (Von Borell & Van Den Weghe, 1999; Verbeke & Viane, 2000) and quality of life (Blokhuys *et al.*, 2000). This resulted in changes that guarantee to consumers choices of new products (Blokhuys *et al.*, 2000; Fraser, 2001).

Confined systems lead to animal stress (Jones & Millis, 1999), resulting in physiological and behavioral responses (Marin *et al.*, 2001) and poor performance (Mendl, 1999). Changes in the raising systems, which decrease stress conditions and allowing selection of strains that may increase comfort and bird welfare, furthermore, increasing zootechnical performance (Blokhuys *et al.*, 2000; Silva Man *et al.*, 2002). Based on these advantages, birds have been raised in semi-confined systems. This new approach has led the Ministry of Agriculture to implement legal policies concerning the criteria for the production, supply, processing, packaging, distribution, and certification of bird quality (DOI/ DIPOA 007/99 of 05/19/1999).

Parameters such as environmental and nutritional conditions, age, strain and sex may influence meat poultry quality and yield (Silva & Nakano, 1998). An adequate adjustment of the nutritional level for broiler chickens requires the knowledge on body composition and bird growth potential, and will be followed by increased performance and



profits (Hruby *et al.*, 1996). Therefore, growth curves may help to define specific nutritional programs and optimal age at slaughter.

The aim of this research was to evaluate the effect of raising systems (confined and semi-confined) on the growth and performance of free-range broiler chicken strains, as well as on meat quality, carcass yield, and yields of parts and organs.

MATERIAL AND METHODS

This experiment was carried out at the Poultry Facilities of Faculdade de Ciências Agrárias e Veterinárias – FCAV, UNESP, Jaboticabal, São Paulo, Brazil. A completely randomized design was used, with eight treatments and five replicates per treatment. The treatments were established in a 2 x 2 x 2 factorial arrangement (2 strains; 2 sexes; 2 raising systems).

Two meat-type broiler strains were used: Paraíso Pedrês (PP) and ISA Label – ISA JA 57 (ISA). There were 490 birds of each strain, and half of each sex. Two hundred and ninety birds of each strain were housed in a confined system and 200 in a semi-confined system.

In the confined system, one-day-old birds were placed in pens of open poultry houses. In this system, 145 birds of each sex and strain were divided in five replicates of 29 birds. Semi-confined birds were placed in 20 paddock areas of 75 m², which were subdivided into pasture (71.25 m²) and a covered area (3.75 m²) for feeding and resting purposes. In this system, 100 birds from each sex and strain were divided into five replicates of 20 birds. The birds were kept under the covered area from 7:00 pm to 7:00 am and had free access to pasture after 28 days of age.

Birds of both systems were fed the same diet, composed of corn, soybean meal, soybean oil, limestone, calcium phosphate, salt, and mineral and vitamin mixture. The diets were formulated based on the chemical composition of ingredients and broiler nutritional requirements proposed by Rostagno *et al.* (2000). Birds received feed and water *ad libitum* throughout the experimental period. Diet levels were 2900 kcal ME/kg and 20.69% CP from 1 to 21 days; 3000 kcal ME/kg and 18.68% CP from 22 to 49 days; 3100 kcal ME/kg 17.43% CP, from 50 to 77 days and 3150 kcal ME/kg and 17.438 % CP from 78 to 105 days.

Maximum and minimum mean ambient temperatures during the fifteen-week experimental period were 34.2°C and 25.3°C, respectively, in the confined system, and 33.4°C and 23.9°C, respectively, in the semi-confined system. Maximum and minimum

relative humidity was 78.9 and 47.9% in the confined system and 85.5 and 52.0% in the semi-confined system.

Birds and diets were weighed weekly to determine mean body weight (g), weight gain (g/bird), feed intake (g/bird), and feed-to-gain ratio. When birds had attained commercial body weight (2.5 kg for males), three females and three males per replicate were fasted for 12 hours and then slaughtered. The age at slaughter was 63 and 77 days old for Paraíso Pedrês and ISA Label, respectively. Broilers were slaughtered by cervical dislocation and bled. Carcasses were immersed in hot water (60°C) for 20 s prior to plucking, followed by manual evisceration and removal of the abdominal fat (gizzard fat + abdominal fat). After pre-chilling in water at 20°C for 30 min, chilling was performed at zero to 8 °C for 15 min. Carcasses and parts were weighed to calculate carcass yield, and the yields of breast drumstick, thigh, drumstick + thigh, wings, back, feet, head + neck, abdominal fat, and organs (intestines, liver, gizzard, heart and proventriculus). Carcass yield was calculated as the ratio between the cold carcass (without legs, head, and neck) and weight after fasting. Breast, drumstick, thigh, drumstick + thigh, wings, and back yield (%) were calculated as the ratio between the weight of each part and cold carcass weight. Percentages of feet, head + neck, intestines, liver, gizzard, heart, and proventriculus were obtained by the ratio between the weight of each part and the weight after fasting.

Two breasts of each parcel were randomly chosen for meat quality analysis and the meat was refrigerated for 24 hours. Physicochemical characteristics of breast muscle samples, such as water holding capacity, pH, water-cooking losses, texture, and meat color were evaluated. Cooking losses were calculated using the weight of samples before and after cooking in water bath at 70°C for 90 min (Purchas cited by Silva Sobrinho, 1999). Shearing force was determined using a Texture Analyzer and a Warner-Bratzler device, which measures shearing (kg). Samples at room temperature (1.5 cm long) were placed in the analyzer to determine the maximum force needed to cut using two parallel scalpel blades 1 cm apart.

Water holding capacity was determined according to the modified method described by Silva Sobrinho (1999). Meat samples (2.0 g) were placed on paper filter (Wattman #1, 11 mm diameter) and between two acrylic plates, over which a 10-kg weight was laid for 5 min. The results were expressed as percentage of water released during the pressing process.



A Colorimeter (Minolta) was used to determine color. The system employs three measures: L* coordinate (black/white) for lightness, a* (green/red) for red content, and b* (blue/yellow) for yellow (Miltenburg *et al.*, 1992; Simões & Ricardo, 2000). pH was measured in breast muscles and chilled carcasses (24 h after slaughter) using a pHmeter (IpHPJ model, Johnis).

Initially, the Spline linear regression model was used to fit the growth curves. However, this model did not represent the best fit for the potential growth curves. Therefore, Gompertz non-linear growth model (Gompertz, 1925) was used and fitted the data better than the Spline model, especially for the inflection point of the curve. Growth curves were developed based on mean body weight using the formula:

$$P_t = P_m \cdot \exp(-\exp(-b \cdot (t - t^*)))$$

where:

P_t = weight (g) of animal at t time, expressed as function of P_m;

P_m = mature weight (g);

b = maturity constant (per day);

t* = time (days) for maximum growth rate.

Thereafter, growth rates were calculated (g/day) according to t time, estimated by equation derivatives. Gompertz function and its parameters were fitted to data using the STATISTICA software (STATISTICA, 1996).

Performance, carcass yield, and meat quality data were analyzed using ANOVA-Statistical Analysis System (6.12 version, SAS, 1989) according to the following model:

$$Y = \mu + S_i + L_j + X_k + (S \times L)_{ij} + (S \times X)_{ik} + (L \times X)_{jk} + (S \times L \times X)_{ijk} + E_{ijkl}$$

Where:

μ = overall mean;

S_i = raising system effect i (i=1, 2);

L_j = strain effect j (j=1, 2);

X_k = sex effect k (k=1, 2);

(S×L)_{ij} = interaction between i system and j strain;

(S × X)_{ik} = interaction between i system and k sex;

(L × X)_{jk} = interaction between j system and k sex;

(S × L × X)_{ijk} = interaction between i system, j strain, and k sex;

E_{ijkl} = error associated to each observation.

Means were compared using Tukey's Test (5%).

RESULTS AND DISCUSSION

Growth curves

The parameters estimated using the Gompertz function (Table 1) showed higher growth potential for males than for females in both raising systems.

Table 1 - Estimates of parameters and determination coefficient (r²) of the Gompertz model for live weight of different strains raised in confined and semi-confined systems.

Parameters	Males	Female
Paraíso Pedrês – confined		
P _m ¹ (g)	4764	4222
b ² (per day)	0.0318	0.0264
t* ³ (days)	44	48
r ²	0.99	0.99
ISA Label – confined		
P _m ¹ (g)	4320	3136
b ² (per day)	0.0280	0.0237
t* ³ (days)	52	53
r ²	0.99	0.98
Paraíso Pedrês – semi-confined		
P _m ¹ (g)	5291	4379
b ² (per day)	0.0291	0.0257
t* ³ (days)	48	50
r ²	0.99	0.99
ISA Label – semi-confined		
P _m ¹ (g)	4347	3247
b ² (per day)	0.0278	0.0237
t* ³ (days)	52	53
r ²	0.99	0.99

1- P_m (kg) = mature weight. 2- b (per day) = maturity rate. 3- t* (day) = age at maximum growth rate. Gompertz equation: $P = P_m \cdot \exp(-\exp(-b \cdot (\text{age} - t^*)))$.

High estimates for mature weight were observed in semi-confined PP birds. However, for both strains, the semi-confined system provided better growth potential, which may be due to a higher tolerance to this raising system, in addition to higher welfare. According to Blokhuis *et al.* (2000) and Silva Man *et al.*, (2002), changes in the raising environment in order to reduce stress, together with selection of more resistant birds, may contribute to animal welfare and, consequently, better performance. Therefore, these facts may explain the higher growth of semi-confined birds and the good performance of PP strain.

In both systems, maturity rates (b*) of live weight for PP males and females were higher than the estimates of growth rates of ISA males and females, which indicates different growth potential of PP birds. Raising systems influenced b* in both strains, so that confined birds exhibited more accelerated b*. Fialho (1999) observed that changes on b* altered the growth curve. Higher values of b* lead to well distributed



growth along time. Similar results occurred analyzing maximum growth rate (t^*) between strains PP and ISA in both systems and estimated t^* values for PP birds were 44 and 48 days of age for confined males and females, respectively, and 48 and 50 days of age for semi-confined males and females, respectively. Estimated t^* values for ISA birds were 52 days for males and 53 days for females in both systems.

Table 1 shows the values of mature weight for semi-confined PP males (5291g) and females (4379g) and ISA males (4347g) and females (3247g). Maximum growth rate (t^*) occurred at 48 and 52 days for males and 50 and 53 days for females of PP and ISA strains, respectively. Figueiredo *et al.* (2003b) evaluated birds raised in semi-confined system and reported mature weight of 3961g and 3471g and maximum growth rate (t^*) of 49.08 and 49.3 days for males and females of Embrapa 041 and ISA strains, respectively.

Semi-confined PP male birds showed the highest growth potential, so that the growth was more accelerated after 10 weeks of age due to welfare. The older birds exhibited lower growth rates and weight gain. The standard acceleration changing point or the inflection point in the curve is the point where the curve changes from concave to convex.

Figures 1 and 2 show the growth curve rates obtained from growth curves. The maximum rate of gain in semi-confined PP was 56.69 g/day at 48 days for males and 41.35 g/day at 50 days of age for females. In the confined system, maximum rate gain was 55.68 g/day at 44 days and 40.98 g/day at 48 days for males and females, respectively. Additionally, in semi-confined ISA Label birds, this parameter was 44.49 g/day at 52 days of age for males and 28.28 g/day for females, whereas in confined ISA Label it was 44.52 g/day for males and 27.31 g/day for females.

Gompertz curve characteristics are around the inflexion point, where maximum growth rate is achieved (Fialho, 1999). In practice, the exact inflexion point is not important, but the length of time during which the growth rate is constant, since the highest deposition of meat in broilers occurs at this point. The convex segment of the curve coincides with the period during which there is a progressive reduction in protein deposition rate, but the body fat growth still occurs until certain age. Afterwards, fat growth also declines and the curve reaches zero, which means that the adult weight has been attained. Generally, PP exhibited higher growth potential than ISA and semi-confined systems allowed higher growth potential for both strains, which agrees with results reported by Figueiredo *et al.* (2003b).

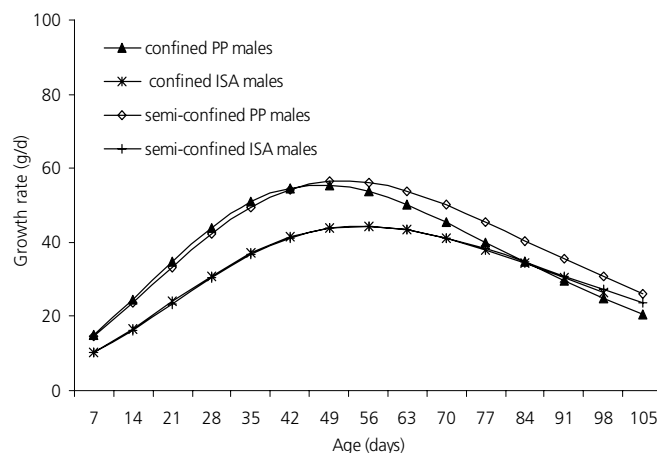


Figure 1 - Growth rates of ISA Label (ISA) and Paraíso Pedrês (PP) males.

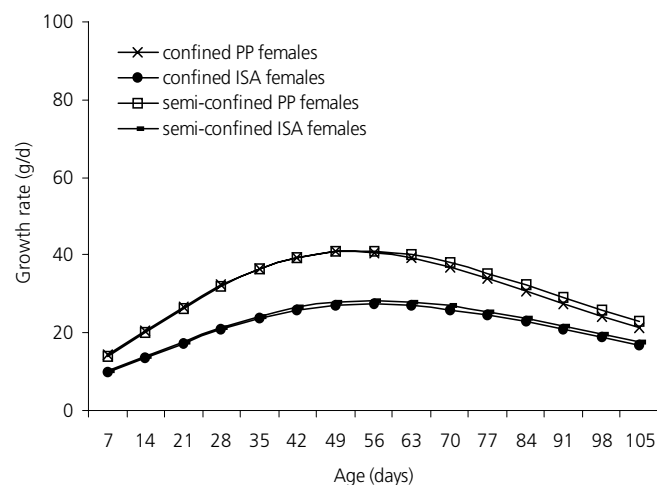


Figure 2 - Growth rates of ISA Label (ISA) and Paraíso Pedrês (PP) females.

Performance

The raising system, strain, and sex had significant effect ($p < 0.05$) on weight gain, feed intake and feed-to-gain ratio. However, the results were significantly influenced by interactions between system and strain and between sex and strain. Performance data of both strains are shown in Table 2.

Body weight gain for both strains in the semi-confined system was higher than that in the confined system, what may be due to bird comfort and welfare. According to Silva & Silva. (2001), changes on the raising environment, which decrease stressful conditions and select more resistant strains, may have improved birds' comfort, welfare and performance.



Paraíso Pedrês birds exhibited better feed-to-gain ratio than ISA, in both raising systems. These results are in agreement with findings reported for four free-range broiler strains with free access to pasture and fed commercial diets *ad libitum* (Carrijo *et al.*, 2002). The authors also reported higher BWG in PP than Carijó Pesado and ISA, but there were no differences from Vermelho Pesado strain (Carrijo *et al.*, 2002).

An interaction was seen between raising system and strain on feed intake in birds from 1 to 21 days of age and from 1 to 49 days old (Table 2). In the same periods, ISA birds showed no differences due to the raising system. However, confined birds exhibited higher feed intake from 1 to 77 days old and from 1 to 105 days old. Such pattern was similar to PP in all periods. Considering the fact that birds raised in the semi-confined system had free access to pasture at 28 days of age, feed intake up to 21 days old could be similar to the feed intake of birds in the confined system. Other explanation can be based on environmental effects, but such effects could not be identified. On the other hand, free access to pasture allows birds to eat plants and insects, which can decrease feed intake.

Paraíso Pedrês birds exhibited better feed-to-gain ratio than ISA in all periods. This can be explained by the high growth potential of PP and, consequently, high feed intake. Rabello (1996) found greater initial growth potential and higher feed intake for Hubbard birds in comparison with other strains.

There was interaction between raising system and strain on feed intake from 1 to 21 days of age. At this period, similar feed-to-gain ratio was observed for both strains in the confined system. However, semi-confined

PP birds presented better feed-to-gain ratio than ISA birds, due to significant differences on weight gain and feed intake. Therefore, PP exhibited better feed-to-gain ratio than ISA. These results are not in agreement with Carrijo *et al.* (2002), who reported no differences between the two strains.

Semi-confined birds exhibited better feed-to-gain ratio in all periods, considering the system effect, associated to lower feed intake and higher weight gain. Interaction between sex and strains for PP and ISA are presented in Table 3.

PP and ISA males exhibited higher mean weight gain ($p < 0.05$) and growth potential than females. Both PP males and females showed higher weight gain ($p < 0.05$) than ISA. Sex influenced feed-to-gain ratio ($p < 0.05$) and males had better feed performance than females. Males exhibited higher growth rates than females, except for ISA from 1 to 21 days, which was explained by a bird that was wrongly sexed. The error was corrected at 21 days of age.

Yields of carcass, parts, and organs

Mean yields of carcass, parts, and organs, and the physicochemical parameters are shown in Table 4. No interaction was observed for these variables ($p < 0.05$).

No differences in yields of feet, carcass, breast, drumstick, thigh, drumstick + thigh, wings, and back and abdominal fat was observed between strains. On the other hand, head + neck ratio, as well as liver and proventriculus relative weights were higher in PP than ISA. The age at slaughter is often used to determine body weight, which is different for each strain and may influence yields of carcass and parts in broiler chickens.

Table 2 - Performance of two free-range broiler strains raised in confined or semi-confined systems

	Weight gain (g)		Feed intake (kg)		Feed-to-gain ratio	
1-21 days						
Strain	Confined	Semi-confined	Confined	Semi-confined	Confined	Semi-confined
Paraíso Pedrês	526 ^{Ab}	653 ^{Aa}	0.85 ^{Aa}	0.69 ^{Ab}	1.62 ^{Ab}	1.06 ^{Aa}
ISA Label	359 ^{Bb}	458 ^{Ba}	0.59 ^{Ba}	0.59 ^{Ba}	1.64 ^{Ab}	1.30 ^{Ba}
CV (%)	2.45		4.62		5.33	
1-49 days						
Paraíso Pedrês	1774	1865	4.04 ^{Aa}	3.66 ^{Ab}	2.28	1.96
ISA Label	1233	1328	2.76 ^{Ba}	2.64 ^{Ba}	2.27	2.00
CV (%)	3.47		4.36		4.14	
1-77 days						
Paraíso Pedrês	2912	3051	8.24 ^{Aa}	7.29 ^{Ab}	2.85	2.39
ISA Label	2142	2231	6.11 ^{Ba}	5.57 ^{Bb}	2.93	2.53
CV (%)	3.0		3.36		2.65	
1-105 days						
Paraíso Pedrês	3748 ^{Ab}	4021 ^{Aa}	12.17	11.84	3.25	2.95
ISA Label	2874 ^{Bb}	3003 ^{Ba}	9.56	9.14	3.39	3.06
CV (%)	3.18		4.0		3.38	

Means followed by different capital letters in the columns and small letters in the rows are significantly different according to Tukey's test ($p < 0.05$).

**Table 3** - Interaction between sex and strain for mean weight gain, feed intake and feed-to-gain ratio of male and female ISA Label and Paraíso Pedrês broilers reared in different raising systems

	Weight gain (g)		Feed intake (kg)		Feed-to-gain ratio	
1-21 days						
Strains	Male	Female	Male	Female	Male	Female
Paraíso Pedrês	625 ^{Aa}	554 ^{Ab}	0.80 ^{Aa}	0.74 ^{Ab}	1.31	1.37
ISA Label	395 ^{Ba}	422 ^{Bb}	0.58 ^{Ba}	0.61 ^{Ba}	1.48	1.46
CV (%)	2.45		4.62		5.33	
1-49 days						
Paraíso Pedrês	2012 ^{Aa}	1628 ^{Ab}	4.17 ^{Aa}	3.53 ^{Ab}	2.08 ^{Ba}	2.17 ^{Aa}
ISA Label	1475 ^{Ba}	1086 ^{Bb}	2.89 ^{Ba}	2.50 ^{Bb}	1.96 ^{Aa}	2.31 ^{Bb}
CV (%)	3.47		4.36		4.14	
1-77 days						
Paraíso Pedrês	3375 ^{Aa}	2588 ^{Ab}	8.46	7.08	2.51 ^{Aa}	2.74 ^{Ab}
ISA Label	2630 ^{Ba}	1744 ^{Bb}	6.46	5.22	2.46 ^{Aa}	3.00 ^{Bb}
CV (%)	3.0		3.36		2.65	
1-105 days						
Paraíso Pedrês	4230 ^{Aa}	3559 ^{Ab}	12.69 ^{Aa}	11.32 ^{Ab}	3.00 ^{Aa}	3.20 ^{Ab}
ISA Label	3452 ^{Ba}	2424 ^{Bb}	10.31 ^{Ba}	8.39 ^{Bb}	2.99 ^{Aa}	3.47 ^{Bb}
CV (%)	3.18		4.0		3.38	

Means followed by different capital letters in the columns and small letters in the rows are significantly different according to Tukey's test ($p < 0.05$).

According to the growth curves already presented, the growth rates were different. PP exhibited higher growth rate than ISA, therefore achieving earlier the ideal weight for slaughter. Additionally, the standardization of slaughter weight to 2.5 kg of live weight resulted in no differences between strains considering both carcass yield and parts yield. However, ISA birds should be slaughtered later than PP to produce the same yields of carcass and parts. Figueiredo *et al.* (2003a) observed that ISA birds had smaller carcass size and less abdominal fat than Ross and EMBRAPA 041 strains when slaughtered at the same age.

As for sex effect (Table 4), males exhibited higher feet and heart relative weights, while females showed higher breast and abdominal fat yields. Similar results have been reported by Figueiredo *et al.* (2003a). Sex had no effect on carcass yield, corroborating results reported by Pescatore *et al.* (1992). On the other hand, Mendes *et al.* (1993) and Politi *et al.* (1993) reported higher carcass yield in females. Besides, males had higher heart relative weight than females. The present results are not in agreement with Figueiredo *et al.* (2002), who reported bigger or heavier internal organs in males than in females, but higher weight percentages in females than in males.

Raising system influenced gizzard weight. Relative gizzard weight was higher in semi-confined birds (about 2.3 % of weight after fasting) than in confined birds (2.0 % weight after fasting). This result may be attributed to a highly functional gizzard. The intake of fibers and grit might have resulted in greater

development of this organ. There were no differences in gizzard percentage between strains; however, females had greater gizzard relative weight than males. Similarly, Rabello (1996) observed no differences in gizzard relative weight between sexes, whereas Figueiredo *et al.* (2002) have reported that males from four different strains had higher gizzard relative weights.

Meat quality

There were no interactions between strains and raising systems on meat quality parameters (Table 4). However, strains influenced ($p < 0.05$) b^* color (yellowish), pH, and cooking losses. Sex influenced L^* color (luminosity – black/white), and the raising system affected breast meat shearing force. Meat color is an important quality parameter for consumers while choosing poultry meat, and free range birds usually have acceptable color. L^* coordinate and a^* in the breast meat were not different between strains, but ISA presented higher b^* values (intense yellow meat color) than PP.

Post mortem alterations include changes in pH, which ranges from 7.3 to 7.5 in live animals. After death, pH decreases until 5.4 within 2 to 8 h after bleeding, when *rigor mortis* takes place. During this process, lactic acid is formed from glycogen, which decreases meat pH, and it becomes tender and tastier, with its characteristic smell (Cañeque *et al.* 1989). pH values ranged from 5.6 to 5.7 in meat from PP and ISA birds, which are similar to values previously reported. This parameter was influenced by strain and sex. ISA



Table 4 - Mean yield of carcass, parts, and organs, and physicochemical characteristics of male and female free-range broilers raised in confined or semi-confined systems.

Variables	Variables								CV (%)
	Paraíso Pedrês				ISA Label				
	Confined		Semi-confined		Confined		Semi-confined		
	M	F	M	F	M	F	M	F	
Carcass yield (%) ¹	72.4	72.2	73.3	72.5	71.8	71.7	72.3	71.9	3.2
Breast yield (%) ¹	28.5	29.3	28.6	29.6	28.0	29.2	28.4	30.0	2.6
Thigh yield (%) ²	15.0	14.4	14.8	14.7	15.5	14.8	15.4	14.4	5.3
Upper thigh yield (%) ²	15.8	15.5	16.3	16.1	16.2	15.1	16.2	15.3	2.8
Thigh + upper thigh yield (%) ²	30.8	29.9	31.1	30.9	31.7	31.1	31.6	29.7	2.9
Wings (%) ¹	12.3	12.8	12.1	12.5	12.8	12.6	12.6	12.3	4.0
Back (%) ²	26.2	27.6	26.8	26.8	26.7	26.4	26.4	26.6	4.3
Feet (%) ¹	4.2	3.4	4.2	3.5	4.0	3.9	4.1	3.4	6.7
Head + neck (%) ¹	7.0	6.8	7.1	7.3	6.8	6.5	6.9	6.8	5.4
Abdominal fat (%) ²	2.8	3.6	2.5	3.2	2.5	3.1	2.3	3.2	20.0
Liver (%) ¹	1.3	1.6	1.5	1.6	1.3	1.6	1.3	1.5	8.4
Gizzard (%) ¹	1.9	2.0	2.0	2.3	1.9	2.1	2.2	2.6	13.6
Heart (%) ¹	0.4	0.4	0.5	0.4	0.5	0.4	0.5	0.4	12.0
Intestines (%) ¹	3.3	3.4	3.4	3.5	3.1	3.3	2.8	3.4	12.6
Proventriculus (%)	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	16.8
L* color	48.6	50.0	50.8	50.5	49.3	50.2	48.9	51.3	3.3
a* color	3.9	3.3	4.9	3.0	3.0	3.5	3.6	3.4	38.6
b* color	5.7	5.4	6.0	5.3	5.2	7.5	6.4	8.6	23.4
pH	5.7	5.7	5.7	5.8	5.6	5.5	5.7	5.6	1.3
Shearing force (kgf/g)	1.6	1.3	1.9	1.6	1.6	1.2	2.0	1.9	36.3
Water holding capacity (%)	65.5	62.7	65.7	66.2	65.1	65.4	65.4	62.2	4.4
Cooking losses (%)	22.4	22.0	24.6	23.2	19.1	19.6	18.9	19.1	6.6

(1) % live weight. (2) % frozen carcass. Color: L* = lightness; a* = redness; and b* = yellowness.

presented higher pH than PP (Table 4). Meat from males had higher pH (5.69) than from females (5.64) ($p < 0.05$). According to Sãnudo (1992), pH may be influenced by internal factors such as muscle type, species, breed, age, sex, and individual characteristics, and may also be influenced by external factors such as feed, fasting, electrical stimulation and chilling.

Among the organoleptic characteristics, tenderness is considered the most important by consumers, which can be defined as how easy the meat can be chewed or cut. Raising systems did not influence water holding capacity and cooking losses. However, the meat of semi-confined birds was tougher, indicating higher texture and shearing force, which can be explained by exercising during grazing.

Even though no differences were found, birds raised in semi-confined system presented lower water holding capacity and, consequently, meat was less tender than meat of confined birds. Lower water holding capacity indicates losses in the nutritional value through exudates that are released and result in drier and tougher meat (Dabés, 2001). Therefore, semi-confined birds presented better texture, a characteristic that consumers expect. Concerning weight losses at cooking, results corroborate findings reported by Sãnudo (1992), who found weight losses due to the cooking process.

CONCLUSION

The semi-confined system was more efficient to raise free range birds, resulting in better performance. Paraíso Pedrês showed better growth potential and performance than ISA Label birds. On the other hand, ISA had better qualitative characteristics, such as higher texture and more yellowish meat, which are more adequate to supply the demand of consumers for free range products.

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