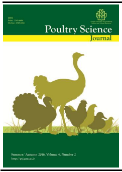

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Carcass Physical Features of Malagasy Chicken: Indigenous Race and Starbro Strain

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Abstract
This study aims to compare anatomies of Madagascar chickens (indigenous race and Starbro strain). With 8,262 individuals of either indigenous races or Starbro strain chickens raised in a suburban environment, the weights of different pieces of cut as well as the live weights before slaughter were determined. Results showed that breast development presents a positive linear relationship with thigh development for Starbro strain chickens (fast growing broiler) while the relationship between the two traits is negative for the indigenous races (slow growing chicken). Giblet proportions are similar between these two types of chicken. We found that slaughtering at 1,750g live weight (age 120 to 185 days) is profitable for indigenous race chickens (meat yield = 40.16%, breast yield = 18.10%, thigh yield = 20.15% and abdominal fat yield = 1.90%). For the Starbro strain, ideal weight at slaughter is 1,300-1,450 g, corresponding to 49 to 61 days of age (meat yield = 39.63%, breast yield = 17.85%, thigh yield = 20.27% and abdominal fat yield = 1.51%). The physical features of the cuts are similar between indigenous races and Starbro strain chickens.

Introduction

Meat provides our main protein supply. The meat production sector has experienced invigorating growth, notably in production, consumption, and world exchange since the mid-80's (FAO, 2000). The poultry industry has proved to be the most dynamic amidst the different meat producing sectors with a yearly expansion of about 5.6% (Devine, 2003). Starting in 2002, poultry meat overran beef to arrive second in world meat consumption (after pork) (Devine, 2003).

Production intensification, industry vertical integration, and price levels were key factors contributing to this development. Farmers aim to supply the necessary quantity to satisfy market demand. On the other hand, meat processors ensure quality is maintained for the sake of consumer wellbeing (ENVT, 2000; INRA, 2000). Therefore, market and offer segmentations, and cut and processed product are important in the progression as well as market development and evolution, and require good control (Devine, 2003). In Madagascar, poultry farming is not a dominant activity of the agricultural economy and does not have quantitative data that support the national economic system (Gama Consult, 2004; Sonalya & Swan, 2004; FOFIFA, 2006). However, poultry

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production provides 20% of daily consumed animal proteins in Madagascar (FOFIFA, 2006), even though national meat consumption remains low (0.8 g per person daily *vs.* 11.9 g per person per day for the world average) in spite of booming modern suburban poultry farming (Albert *et al.*, 2003; France Diplomatie, 2006).

Thus, this study aims to improve knowledge about poultry production efficiency through analyses of the physical features of poultry meat intended for consumption in Antananarivo, Madagascar. These data can be used to create a better strategic orientation geared towards revival of the poultry industry in Madagascar.

Materials and Methods

Data have been gathered from various suburban poultry farms or from different butchers in downtown Antananarivo, Madagascar between November 2006 and April 2007. In total, 8,262 chickens were counted, of which comprised 1,309 individuals of indigenous race and 6,953 Starbro strain chickens. Indigenous race chickens have been raised in an extensive way, but still benefit from a feed supplement at the end of the day while chickens of Starbro strain have been raised more intensively and received a balanced ration twice daily. Farmers took care of the birds' sanitary follow-ups all throughout the production cycle. Cycle length varies from 40 to 61 days for Starbro strain chicken *vs.* 100 to 186 days for indigenous race chickens. A precision scale with a 3 kg range and 1 g precision was used to weigh chicken individually before slaughter and also the pieces of cut after slaughter. JMP/SAS 5.0.1 software was used for data statistical analyses.

In general, chickens are slaughtered the same day they are sold, or the evening before if demand is high. For the latter, carcasses are frozen in whole at night. Chicken live body weights as well as weights of various parts such as thigh, wing, breast, liver and abdominal fat were individually measured.

Elementary descriptive statistical analyses provide a synthetic data presentation along with cut and breast weights by class of chicken live weight qualitative. Comparative analyses were used to show differences between chickens of indigenous race and Starbro strain (Vessereau, 1988; Dagnelie, 1986; SAS/JMP, 2002).

The ratio between thigh weight (as well as wing, liver and abdominal fat weights) and breast weight was computed to demonstrate tendency for noble piece weight evolution according to the class of live weight for each chicken type with eq. (1):

$$\text{Ratio}=\frac{\text{Thigh Weight}}{\text{Breast Weight}}\times 100 \quad \text{(Equation 1)}$$

Breast weight variation in relation to weight of edible meat (thigh, wing, and breast) for each class of live body weight was estimated using eq. (2):

$$\text{Ratio}=\frac{\text{Breast Weight}}{\text{Edible Meat Weight}}\times 100 \quad \text{(Equation 2)}$$

A similar calculation was used to assess slaughterhouse giblets (liver and abdominal fat) weight variation in relation to the weight of edible meat for every class of live body weight using eq. (3):

$$\text{Ratio}=\frac{\text{Slaughterhouse Giblet Weight}}{\text{Edible Meat Weight}}\times 100 \quad \text{(Equation 3)}$$

Productivity was assessed in two ways: chicken meat yield for live weight using eq. (4):

$$\text{Meat Yield}=\frac{\text{Thigh Weight+Breast Weight+Abdominal Fat Weight}}{\text{Live Weight}}\times 100 \quad \text{(Equation 4)}$$

and through a piece of cut weight ratio using eq. (5):

$$\text{Piece of Cut Ratio}=\frac{\text{Piece of Cut Weight}}{\text{Live Weight}}\times 100 \quad \text{(Equation 5)}$$

Results and Discussion

Population characteristics

Individuals weighing 1,300-1,450 g (class 4) are the most common for both the indigenous race (31.55%) (Table 1) and the Starbro strain (28.43%) (Table 2). Based on chicken breast weight, identified as a noble piece of meat, the ratio of the weight of pieces such as wings, liver, and abdominal fat over breast weight is similar between the two strains of chicken (indigenous race and Starbro). In contrast, a peak of the ratio between thigh weight over breast weight (Eq. 1) is noted for class 6 (1.17 for indigenous race chickens and 1.15 for Starbro strain chickens) (Fig. 1). However, among the indigenous race, chickens with a live weight over 1750 g live weight have a relative reduction in thigh weight compared to breast weight: ratios of 1.11 and 1.05 for class 7 and class 8 of chicken live weight, respectively. This relative reduction of the ratio between thigh and breast weights is not observed in Starbro strain chicken (ratios of 1.12

and 1.14 for classes 7 and 8, respectively). These observations show that fast growing chicken have proportional development in their breast and thigh, but slow growing strains, especially over 1750 g live weight, breast development takes place at the expense of thigh weight increase.

In regards to the relative breast weight over total edible meat weight (thigh, wing, and breast), this ratio (Eq. 2) first increased with live weight for Starbro strain chicken and then reached a plateau at a value slightly lower than 39% for class 5 (live weight 1450-1,600 g) (Fig. 2). Comparatively, for the indigenous race, starting at class 6 (live weight 1,600-1,750 g), breast represents a relatively more important part of edible meat make up. This suggests that breast development may be more prominent than development of other pieces of meat in slow growing chicken. In contrast, for fast growing strains, the different piece of meat proportions remains relatively free from live body weight effect.

Table 1. Indigenous race chicken physical features (n = 1309, mean±SE)

(Class) (Live body Weight, g)	(1) (850–1000)	(2) (1000–1150)	(3) (1150–1300)	(4) (1300–1450)	(5) (1450–1600)	(6) (1600–1750)	(7) (1750–1900)	(8) Live Weight> 1900
Rearing period (day)	120–185	120–185	100–186	100–186	100–184	110–183	120–185	127–180
Number of birds	64	131	309	413	252	63	63	14
Frequency (%)	4.89	10.01	23.61	31.55	19.25	4.81	4.81	1.07
Thigh (g)	181.58±2.13	214.11±1.49	246.22±0.97	279.49±0.84	304.81±1.07	343.67±2.15	364.67±2.15	377.00±4.55
Based on Eq. 1 (%)	121.09	116.8	114.1	113.54	113.22	117.74	111.33	105.75
Wing (g)	75.22±1.02	86.92±0.72	99.49±0.47	110.12±0.40	121.53±0.52	135.33±1.03	147.89±1.03	148.50±2.19
Based on Eq. 1 (%)	50.16	47.42	46.11	44.73	45.14	46.36	45.15	41.65
Breast (g)	149.95±3,20	183.31±2.24	215.79±1.46	246.17±1.26	269.22±1.61	291.89±3.22	327.56±3.22	356.50±6.84
Liver (g)	26.5±0.57	30.26±0.40	32.30±0.26	36.61±0.22	38.61±0.29	42.89±0.58	48.67±0.58	61.00±1.22
Based on Eq. 1 (%)	17.67	16.51	14.97	14.87	14.34	14.69	14.86	17.11
Abdominal fat (g)	9.94±0.89	13.04±0.62	14.61±0.40	20.95±0.35	23.50±0.45	23.67±0.89	34.44±0.89	31.50±1.90
Based on Eq. 1 (%)	6.63	7.11	6.77	8.51	8.73	8.11	10.51	8.84
Meat yield (%)	36.37±0.85	37.60±0.93	38.76±1.06	39.61±1.23	39.50±1.29	39.19 ± 1.51	40.16 ± 1.86	39.33±8.70
Thigh yield (%)	19.34±0.33	19.61±0.42	20.02±0.36	20.25±0.42	20.15±0.46	20.43 ± 0.57	20.15 ± 0.55	19.38±2.10
Breast yield (%)	15.97±0.44	16.79±0.39	17.55±0.55	17.84±0.61	17.79±0.64	17.35±0.77	18.10±1.07	18.33±6.15
Abdominal fat yield (%)	1.06±0.09	1.19±0.12	1.19±0.15	1.52±0.20	1.55±0.19	1.41±0.17	1.90±0.24	1.62±0.45

Weights of slaughterhouse giblets (liver and abdominal fat) relative to edible meat weight (Eq. 3) are similar between the two types of chicken (Figure 3). For class 6 chickens (live weight 1600-1750 g), the relative weight of slaughterhouse giblets tends to increase, especially for indigenous race chicken, where it increases over 10% of edible meat weight in chickens of class 8 (>1900 g). In this study, indigenous race chicken (raised on an extensive mode) and Starbro strain chicken (raised on a more intensive system) show similar growth performance patterns. Likewise, liver and abdominal fat development are not directly related to chicken edible meat quantity in neither fast growing nor slow growing race or strain. Thus, it is noted that chickens show the same tendency in body development and piece of cut weight growth. The only significant difference stands in the relative predominance of breast piece in indigenous race chicken during the finishing growth phase. Beside herd size effect on chicken performance level (Delpech, 1984), difference in age at slaughtering, the double for indigenous race chicken compared to that of Starbro strain chicken, would be the main factor (Castellini *et al*., 2002; Baéza *et al*., 2003; Havenstein *et al*., 2003; Cortinas *et al*., 2004; De Marchi *et al*., 2005). Indeed, chicken body growth and development follow physiological rules established during embryonic development (Romanoff, 1960; Mauro, 1961; Moss, 1968; Moss and Leblond, 1971; Kang *et al*., 1985; Ott *et al*., 1990; Murakami *et al*, 1992; Halevy *et al*., 2000;

Mozdziak *et al*., 2002; Berri and Duclos, 2003; Goll *et al*., 2003; Picard *et al*., 2003; Velleman, 2007). Abdominal fat deposit is not directly related to chicken muscular growth, but is often significantly affected by raising management, particularly the bird feeding system (Gunaratne *et al*., 1993; Gunaratne *et al*., 1994; Gunaratne, 1999; Huque, 1999a; Huque, 1999b; Roberts, 1999; Ndegwa *et al*., 2001; Dana and Ogle, 2002; Olukosi and Sonaiya, 2003; De Marchi *et al*., 2005; Gondwe and Wollny, 2005), the animal genetic features (Leclercq, 1983; Ricklefs, 1985; Leclercq, 1989; Leclercq *et al*., 1994; Mitchell and Burke 1995; Duclos and Rémignon 1996; Duclos *et al*., 1996; Alleman *et al*., 1999; Halevy *et al*., 2000; Bigot *et al*. 2001; Havenstein *et al*., 2003; Cortinas *et al*., 2004) and lastly, respect for the farming environmental conditions (Blake and Hess, 2004).

Table 2. Starbro strain chicken physical features (n=6953, mean±SE)

(Class) (Live body Weight, g)	(1) (850–1000)	(2) (1000–1150)	(3) (1150–1300)	(4) (1300–1450)	(5) (1450–1600)	(6) (1600–1750)	(7) (1750–1900)	(8) Live weight> 1900
Rearing period (day)	40– 61	40– 61	49–61	49–61	49–61	49–61	49–61	49–61
Number of birds	340	762	1725	1977	1296	449	338	66
Frequency (%)	4.89	10.96	24.81	28.43	18.43	6.46	4.86	0.95
Thigh (g)	181.24±0.95	212.16±0.63	245.64±0.42	279.80±0.39	304.88±0.49	338.57±0.83	364.41±0.95	371.59±2.15
Based on Eq. 1 (%)	120.43	115.27	114.52	113.53	113.01	115.35	112.51	114.52
Wing (g)	75.04±0.48	86.26±0.32	98.26±0.21	110.18±0.20	121.38±0.24	132.81±0.42	146.57±0.48	148.44±1.08
Based on Eq. 1 (%)	49.86	46.87	45.81	44.71	44.99	45.25	45.25	45.75
Breast (g)	150.49±1.37	184.06±0.91	214.50±0.61	246.45±0.57	269.79±0.70	293.52±1.19	323.90±1.37	324.48±3.11
Liver (g)	26.46±0.25	29.972±0.17	32.10±0.11	36.56±0.11	38.70±0.13	42.14±0.22	48.05±0.26	53.26±0.58
Based on Eq. 1 (%)	17.58	16.28	14.97	14.83	14.34	14.36	14.83	16.41
Abdominal fat (g)	10.08±0.40	13.18±0.27	14.51±0.18	20.90±0.17	23.27±0.21	26.19±0.35	34.13±0.40	30.29±0.91
Based on Eq. 1 (%)	6.7	7.16	6.76	8.48	8.63	8.92	10.54	9.33
Meat yield (%)	36.45±0.87	37.68±1.01	38.64±1.07	39.63±1.20	39.48±1.32	39.16±1.86	39.84±1.83	37.66±4.57
Thigh yield (%)	19.33±0.32	19.52±0.46	19.20±0.36	20.27±0.42	20.13±0.49	20.14±0.64	20.10±0.53	19.27±0.98
Breast yield (%)	16.05±0.46	16.94±0.44	17.46±0.56	17.85± .59	17.81±0.64	17.46±0.85	17.86±1.07	16.82±3.17
Abdominal fat yield (%)	1.08± 0.09	1.21± 0.12	1.18± 0.15	1.51±0.19	1.54±0.19	1.56±0.37	1.88 0.23	1.57±0.43

Meat Yield

Meat yield (Eq. 4) (Fig. 4) and the partial piece of cut yield (Eq. 5) (Fig. 5) are reflections of chicken production performance. Meat yield (Eq. 4) was similar between the two chicken populations. A progressive increase in meat yield is noted from live weight class 1 (36.37% for indigenous race chicken *vs.* 36.45% for Starbro strain) up to class 4 (39.61% *vs.* 39.63%, respectively for the indigenous race and Starbro). A maximum yield is noted at class 7 level among indigenous race (40.16%) or among Starbro strain (39.84%). There are no significant differences in the ratios of piece of cut of different live weight classes of chickens (Eq. 5) (P > 0.05) (Fig. 5a and Fig. 5b), demonstrating that age at slaughtering does not impact ratios and yields in indigenous race nor Starbro strain chickens. However, it could be noted that slaughtering of indigenous race chickens may be most beneficial at class 7 (live weight 1750-1900 g) (Figure 5a) as breast ratio is higher (18.10%) compared to that of class 6, even if thigh ratio (20.15%) is slightly lower than that of class 6 (20.43%). Slaughtering of the Starbro strain would be most profitable in class 4 chickens (live weight 1300-1450 g) (Figure 5b) as thigh ratio (20.27%) and breast ratio (17.85%) are higher. Variations in ratios may be due to effects of age at slaughtering, genetic makeup, and physiological state (Delpech, 1984; Tor *et al*., 2002; Baéza *et al*., 2003).

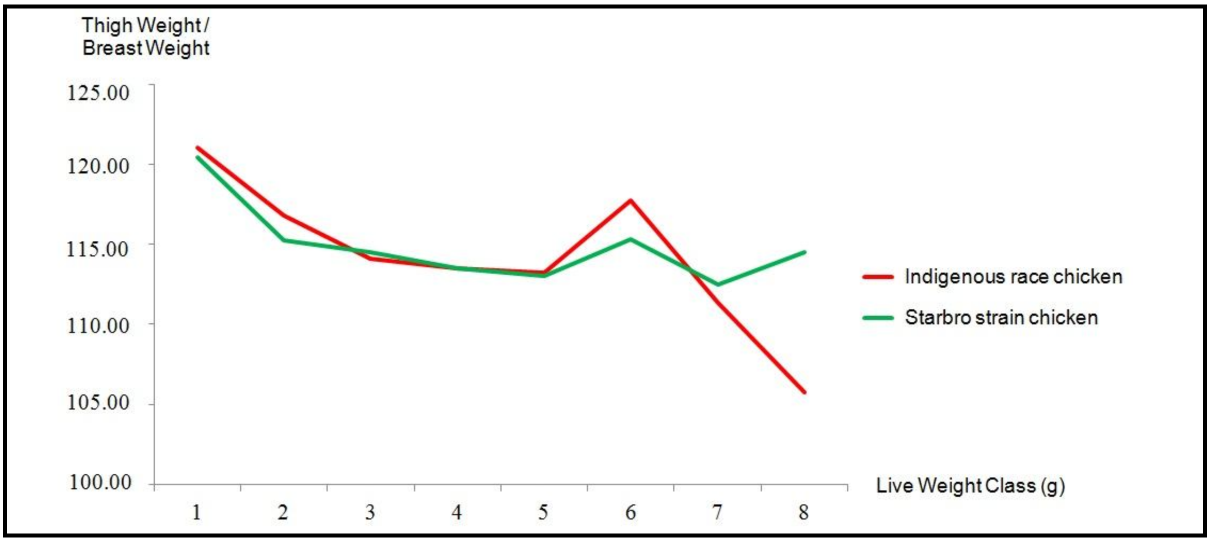

Figure 1. Ratio between Thigh Weight and Breast Weight evolution with chicken Live Weight Class.

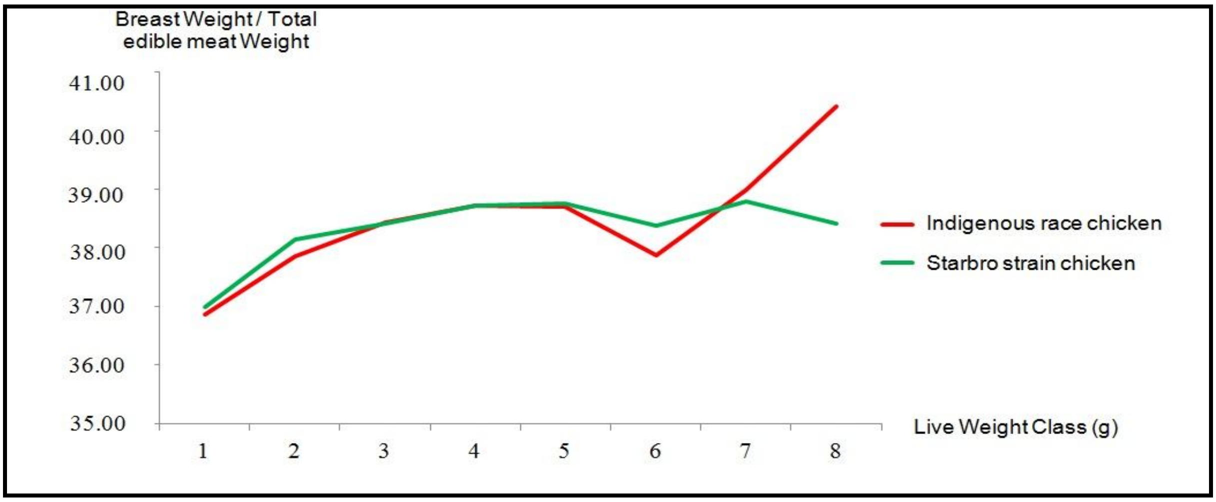

Figure 2. Ratio between Breast Weight and Carcass Weight evolution with chicken Live Weight Class.

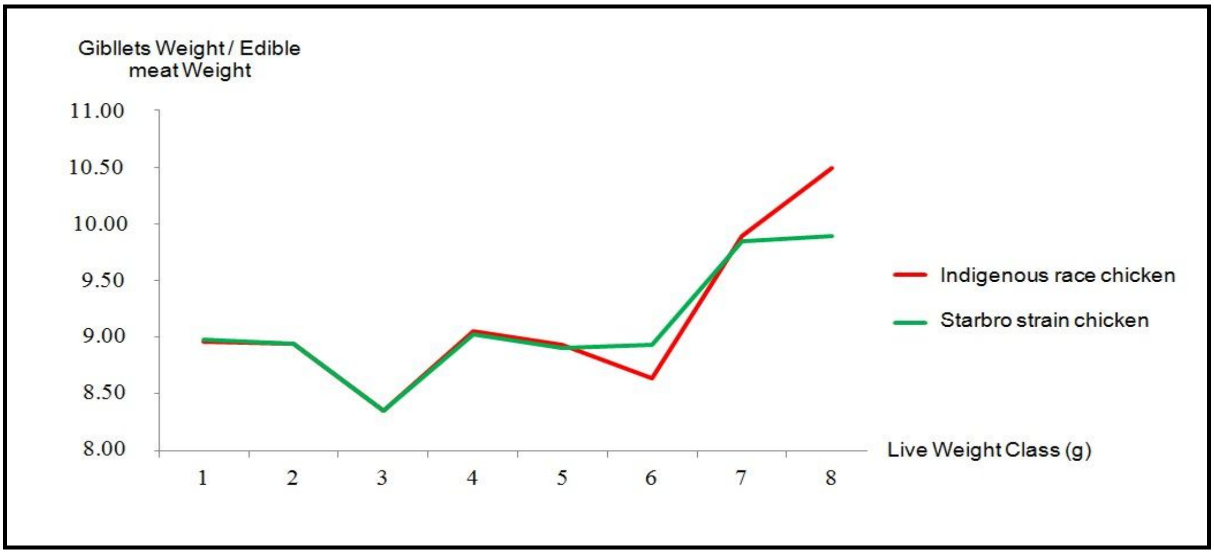

Figure 3. Ratio between Slaughterhouse Giblet Weight and Carcass Weight evolution with chicken Live Weight Class.

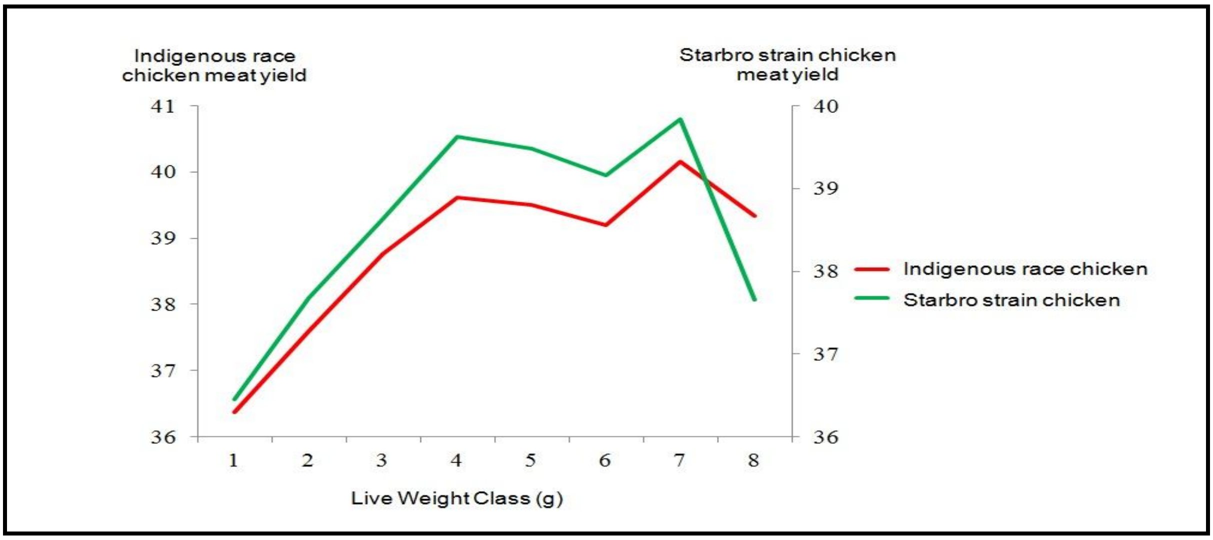

Figure 4. Chicken meat yield evolution with live weight class.

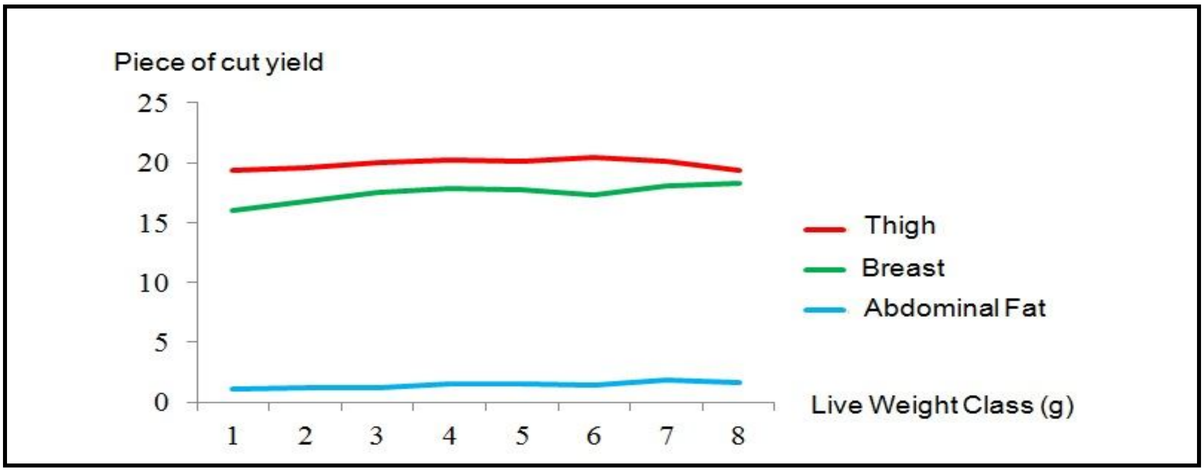

Figure 5a. Indigenous race chicken piece of cut ratio evolution with live weight class.

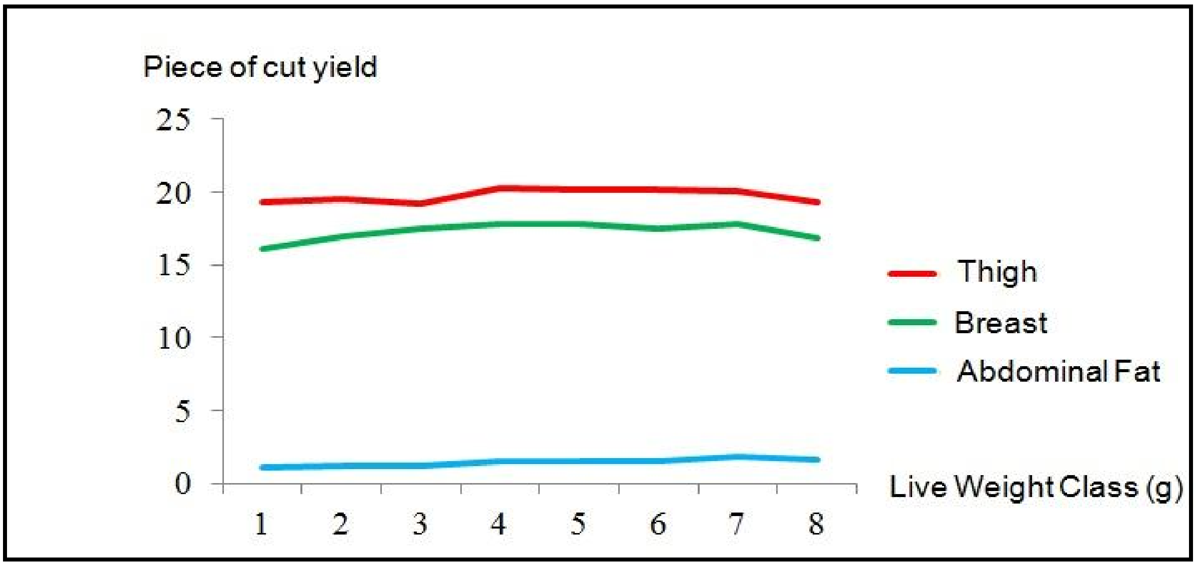

Figure 5b. Starbro strain chicken piece of cut ratio evolution with live weight class.

Conclusion

Two different chicken populations – a fast growing one (Starbro strain) and a slow growing other (indigenous race) – have been studied. Despite being raised in two different systems, physical features of the piece of cut were similar between the two populations. A low growth performance leading to low production efficiency is noted for the whole population. Improving farming techniques and management would increase size of edible meat. However, for better production, setting up a management and decision-making help tool is recommended, especially for revival of the poultry sector with indigenous race chickens.

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References

Albert C., Amand J., Bastiaeli D., Cardinale E., Champagne J., Cothenet G., Drouin P., Goater E., Prin S., Renault P., Rudeaux F., Saboulard M., Revidy J., Valancony H. 2003. ''Broilers production in hot climates.'' Technical Institute in Poultry (ITAVI) Editions, Paris.

Alleman F., Bordas A., Caffin S., Daval S., Diot C., Douaire M., Fraslin J.M., Lagarrigue S., Leclercq B. 1999. ''Fattening in the chicken : metabolic and genetic aspects.'' National Institute of Agronomics Research, Livestock Production, 12: 257-264.

Baéza E., Lessire M., Juin H., Chatrin P., Boreau T., Berri C. 2003. ''Effect of day old on carcass and meat quality of label guinea fowl.'' Fifth Congress of Broiler Chicken Research, Tours, France.

Berri C. & Duclos M.J. 2003. ''Typology and ontogenesis of muscle fibers in birds''. National Institute of Agronomics Research, Livestock Production, 16: 137-143.

Bigot K., Tesseraud S., Taouis M., Picard M., 2001. ''Neonatal and early development of feeding broiler.'' National Institute of Agronomics Research, Livestock Production, 14: 219-230.

Blake JP & Hess JB. 2004. Effect of protein on growth and carcass yield of Emu. International Journal of Poultry Science, 3: 211-214. [Link]

Castellini C, Mugnai C & Dal Bosco A. 2002. Effect of organic production system on broiler carcass and meat quality. Meat Science, 60: 219-225. [Link]

Cortinas L, Villaverde C, Galobart J, Baucells MD, Codony R & Barroeta AC. 2004. Fatty acid content in chicken thigh and breast as affected by dietary polyunsaturation level. Poultry Science, 83: 1155-1164. [Link]

Dagnelie, P. ed. 1986. Theories and statistical methods: agronomic applications. Vol.2. Belgium: Agronomic of Gembloux Press. 464 pages.

Dana N & Ogle B. 2002. Effects of scavenging on diet selection and performance of Rhode Island Red and Fayoumi breeds of chicken offered a choice of energy or protein feeds. Tropical Animal Health Production, 34: 417-429. [Link]

De Marchi M, Cassandro M, Lunardi E, Baldan G & Siegel PB. 2005. Carcass characteristics and qualitative meat traits of the Padovana breed of chicken. International Journal of Poultry Science, 4: 233-238. [Link]

Delpech P. 1984. Broiler meat quality. Technical Bulletin Information, 394-395, 581-596. [Link]

Devine R., 2003. ''Meat products consumption.'' National Institute of Agronomics Research, Livestock Production, 16: 325-327.

Duclos M. J. & Remignon H., 1996. ''Muscle development chickens from lines fast and slow growth.''. National Institute of Agronomics Research, Livestock Production, 9: 224-226.

Duclos MJ, Chevalier B, Remignon H, Ricard FH, Goddard C & Simon J. 1996. Divergent selection for high or low growth rate modifies the response of muscle cells to serum or insulin-like growth factor-I *in vitro*. Growth Regulation, 6: 176-184. [Link]

Food and Agriculture Organization (FAO), 2000. Medium-term prospects for agricultural products: Projection horizon 2005. FAO Edition, Rome, Italy. Report.

France Diplomatie, 2006. ''Animal production competitively in Africa sub-Saharan and Madagascar.'' French Foreign Ministry Report.

Gama Consult. 2004. ''Actual situation and development perspectives studies for chicken farms in Madagascar.'' Maison de la Petite

Elevage, Antananarivo, Madagascar. Final report.
Goll DE, Thompson VF, Li H, Wei WEI & Cong J. 2003. The calpain system. Physiology Reviews, 83: 731-801. [Link]
Gondwe TN & Wollny CBA. 2005. Evaluation of growth potential of Local chickens in Malawi. International Journal of Poultry Science, 4: 64-70. [Link]
Gunaratne S.P., 1999. Feeding and nutrition of scavenging village chickens. First INFPD/FAO, Electronic Conference of Family Poultry. Accessed October, 2000.
Gunaratne SP, Chandrasiri ADN, Wickramaratne SHG, Roberts JA, Djajanegara A & Sukmawati A. 1994. The utilisation of scavenging feed resource base for village chicken production. Proceedings Seventh Asian Australasian Association for Animal Production Congress, Bali, Indonesia, 2: 67-68. [Link]
Gunaratne SP, Chandrasiri ADN, Hemalatha WAPM & Roberts JA. 1993. Feed resource base for scavenging village chickens in Sri Lanka. Tropical Animal Health and Production, 25: 249-257. [Link]
Halevy O, Geyra A, Barak M, Uni Z & Sklan D. 2000. Early post-hatch starvation decreases satellite cell proliferation and skeletal muscle growth in chicks. Journal of Nutrition, 130: 858-864. [Link]
Havenstein GB, Ferket PR & Qureshi MA. 2003. Carcass composition and yield of 1957 versus 2001 broilers when fed representative 1957 and 2001 broilers diets. Poultry Science, 82: 1509-1518. [Link]
Huque QME. 1999b. Nutritional status of family poultry in Bangladesh. First INFPD/FAO Electronic Conference of Family Poultry. Accessed October, 2000. [Link]
Huque, Q.M.E. 1999a. Poultry research in Bangladesh: present status and its implication for future research. In F. Dolberg and P.H. Petersen, eds. Poultry as a Tool in Poverty Eradication and Promotion of Gender Equality: 151-164. Proceedings workshop, March 22-26, 1999, Tune Landboskole, Denmark. http://www.husdyr.kvl.dk/htm/php/tune99/15-Haque.htm.
Kang CW, Sunde ML & Swick RW. 1985. Growth and protein turnover in the skeletal muscles of broiler chicks. Poultry Science, 64: 370-379. [Link]
Leclercq B. 1983. The influence of dietary protein content on the performance of genetically lean or fat growing chickens. Broad Poultry Science, 24: 581-587. [Link]
Leclercq B., 1989. ''Potential leads and interest Lean genotypes in poultry". National Institute of Agronomics Research, Livestock Production, 2: 275-286.
Leclercq B, Chagneau AM, Cochard T & Khoury J. 1994. Comparative responses of genetically lean and fat chickens to lysine, arginine and non-essential amino acid supply. I. growth and body composition. British Poultry Science, 35: 687-696. [Link]
Mauro A. 1961. Satellite cell of skeletal muscle fibers. Journal of Biophysical and Biochemical Cytology, 9: 493-495. [Link]
Mitchell RD & Burke WH. 1995. Posthatching growth and pectoralis muscle development in broiler strain chickens, bantam chickens and the reciprocal crosses between them. Growth, Development, and Aging, 59: 149-161. [Link]
Moss FP & Leblond CP. 1971. Satellite cells are source of nuclei in muscles of growing rats. Anatomical Record, 170: 421-435. [Link]
Moss FP. 1968. The relationship between the dimensions of the fibers and the number of nuclei during normal growth of skeletal muscle in the domestic fowl. American Journal of Anatomy, 122: 555-563. [Link]
Mozdziak PE, Walsh TJ & McCoy DW. 2002. The effect of early post-hatch nutrition on satellite cell mitotic activity. Poultry Science, 81: 1703-1708. [Link]
Murakami H, Akiba Y & Horiguchi M. 1992. Growth and utilization of nutrients in newly-hatched chick with or without removal of residual yolk. Growth, Development, and Aging, 56: 75-84. [Link]
National Institute of Agronomics Research (INRA), 2000. ''Carcass quality and broiler meat.'' Information and Communication Service. National Institute of Agronomics Research, Research Center of Tours. Research note.
National Research Center for Agricultural (FOFIFA), 2006. ''Village poultry in Madagascar: Actual situation and test improvement.'' Accessed December 20, 2005.
National Veterinary School of Toulouse (ENVT), 2000. ''Food quality.'' Hygiene and Inspection of Foodstuffs of Animal Origin. Courses.

Ndegwa JM, Mead R, Norrish P, Kimani CW & Wachira AM. 2001. The growth performance of indigenous Kenyan chickens fed diets containing different levels of protein during rearing. Tropical Animal Health Production, 33: 441-448. [Link]

Olukosi OA & Sonaiya EB. 2003. Determinationof the quantity of scavenge able feed for family poultry on free range. Livestock Research for Rural Development, 15. [Link]

Ott MO, Robert B, Buckingham M, 1990. Origin of the muscle. Medicine Science, 6: 653-663.

Picard B, Jurie C, Cassar-Malek I, Hocquette JF, Lefaucheur L, Berri C, Duclos MJ, Alami-Durante H, Rescan PY. 2003. Typology and ontogenesis of muscle fibers in different species of agronomic interest. National Institute of Agronomics Research, Livestock Production, 16: 117-123.

Ricklefs RE. 1985. Modification of growth and development of muscles of poultry. Poultry Science, 64: 1563-1576. [Link]

Roberts JA. 1999. Utilisation of poultry feed resources by smallholders in the villages of developing countries. In F. Dolberg & P.H. Petersen, eds. Poultry as a Tool in Poverty Eradication and Promotion of Gender Equality: 311-336. Proceedings workshop, March 22-26, 1999, Tune Landboskole, Denmark. http://www.husdyr.kvl.dk/htm/php/tune99/28-roberts.htm

Romanoff AL. 1960. The avian embryo. Structural and functional development. The Macmillan Company, New York, USA. 1305pages. [Link]

Sonaiya EB & Swan SEJ. 2004. Small-scale poultry production: technical guide. Animal Production and Health Division, Food and Agriculture Organization Editions. 109pages. [Link]

Statistical Analysis System (SAS/JMP), 2002.User's guide Statistics JMP/SAS, version 5, SAS Institute INC., Cary, NC.

Tor M, Estany J, Villalba D, Molina E & Cubló D. 2002. Comparison of carcass composition by parts and tissues between cocks and capon. Animal Research, 51: 421-431. [Link]

Velleman SG. 2007. Muscle development in the embryo and hatchling. Poultry Science, 86: 1050-1054. [Link]

Vessereau A. ed. 1988. Statistical Methods in Biology and Agronomy. Paris: Technique & Documentation Lavoisier. 127pages. [Link]