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Growth rate, carcass traits and meat quality of slow-growing chicken grown according to three raising systems*

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The experiment was conducted to study the effect of indoor-floor, indoor-net and free-range raising systems on growth rate, carcass traits and meat quality of slow-growing broiler chicken. One-day old Gushi chicks were raised until day 35 of life. On day 36, 135 female birds of similar body weight (mean 354 g), were randomly selected and assigned to one of three raising systems (indoor-floor, indoor-net and free-range), each with three replicates of 15 birds (*i.e.* 45 birds per system). Both the indoor-floor and indoor-net systems were run in pens with solid or net floor, respectively, in a poultry research house (7 birds/m^2). The free-range system was run in a similar indoor house (7 birds/m^2), but with a free access of birds to grassy paddock (1 bird/m^2). All birds were offered the same diets and were kept growing for 112 days. The body weight and body weight gain of birds from free-range system were found to be significantly lower than of those kept in indoor-floor system (P <0.05), while for feed conversion ratio (feed/gain) the reverse relation (P <0.05) was observed. There was no difference in eviscerated carcass, and breast and thigh percentages among three raising systems (P>0.05), while the systems significantly affected the abdominal fat and stomach per cent of carcass, and tibia strength (P<0.05). The water, protein and fat contents, water-holding capacity, shear force and pH of the meat were unaffected (P>0.05) by the raising system. It is concluded that in slow-growing chicken the free-range raising system had significant effect on growth performance, but only limited on carcass traits and meat quality, except for abdominal fat, stomach percentage and tibia strength.

KEY WORDS: carcass / chicken / growth rate / raising system / slow-growing chicken / meat quality

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For the past five years the organic market in China has grown annually by more than 30% [Jin 2008], and poultry products are part of this trend. Production of special poultry products in China is accomplished through natural and organic production systems, which avoid the use of dietary animal by-products and antibiotics for birds' growth. Many consumers believe these products have superior sensory qualities and report that they "taste better" [Latter-Dubois 2000]. Whereas some countries (e.g. European Union and USA) have very specific definitions for free-range or other special production, China has not. Production systems vary widely from large stationary houses with yards to small portable houses that are moved frequently to new pasture.

Conventional confined systems of keeping chicken lead to bird's stress [Jones and Millis 1999], resulting in physiological and behavioural responses [Marin *et al*. 2001] and poor performance [Mendl 1999]. Outdoor production system, without any confinement can reduce stress and increase comfort and bird welfare, furthermore leading to products' better taste and flavour compared to conventionally produced broiler chicken [Lewis *et al*. 1997, Fanatico *et al*. 2006]. Based on these advantages, birds have been raised according to outdoor systems. This new approach has led the Ministry of Agriculture of China to implement legal policies concerning the criteria for poultry products and certification of their quality.

The objective of present study was to evaluate the effect of indoor-floor, indoor-net and free-range raising systems on growth rate, carcass traits and meat quality of slow-growing chicken.

Material and methods

Experimental design and bird management

The trial was carried out at Poultry Institute of the Chinese Academy of Agricultural Sciences (Yangzhou) from March to July 2005, on female chicks of the Gushi slow-growing chicken variety. Four-hundred Gushi chicks, one-day old, were kept growing until day 35 of life. On day 36, 135 healthy female birds of similar body weight (mean 354 g) were randomly selected and assigned to one of three raising systems (indoor-floor, indoor-net and free-range) with three replicates of 15 birds in each system (*i.e*. a total of 45 birds per system).

The birds **of indoor-floor system** were raised in pens fitted with the solid floor, in a poultry research house that contained side curtains and fans for ventilation and cooling. Density in each pen was 7 birds/m^2, the temperature 20±3°C, the relative humidity 65-75%, and the photoperiod 12h.

The **indoor-net system** was similar to the indoor-floor system, except for wire netting (1×1 cm) instead of the solid floor.

The **free-range system** was run in a similar indoor house (7 birds/m^2), but with a free access to grassy paddock (1 bird/m^2). Feed and water were also provided outdoors using trough feeders and water pans with reservoirs. Ground predators were excluded by electric net fencing, and overhead predators were excluded by netting over the paddocks. Birds were confined to indoor pens at night.

All birds were fed the same diet (day 1 to 35 – starter, day 36 to slaughter – finisher (Tab. 1). Access to feed and water was free, and diets were formulated according to National Reseach Council [1994] feeding standards.

Table 1. Selected nutrient and energy contents of feeds[1]

Item	Starter	Finisher
Crude protein (%)	21.63	19.07
Metabolizable energy (MJ/kg)	12.55	12.97
Crude fibre (%)	4.05	4.25
Calcium (%)	1.09	0.96
Available phosphorus (%)	0.49	0.46
Methionine (%)	4.02	3.88
Lysine (%)	8.81	8.75

[1]Feeds and results of their analyses were provided by Yangzhou Hope Feed Co.

Sampling and analyses

Birds and feed were weighed weekly to determine body weight and feed intake, and to calculate the feed efficiency ratio. On day 112, after 10 hours fasting, all birds were weighed individually and slaughtered by manual exsanguination. After manual evisceration, the carcass, stomach, abdominal fat, breast meat (including *pectoralis major* and *pectoralis minor* muscles) and leg meat (including thigh and drumstick meat) were weighed. Per cent of eviscerated carcass was calculated as the ratio between the eviscerated carcass and live body weight after fasting. The percentages of weights of breast meat, leg meat, stomach and abdominal fat were calculated in relation to eviscerated carcass weight.

Left drumsticks of all birds were deboned and bone breaking strength of the tibia was determined with a Texture Analyzer (American FTC Co. – TMS-2000) – 72 h *post mortem.*

Muscle samples of all birds were collected from left side of *pectoralis major* muscle for meat quality evaluation. Physico-chemical traits of breast muscle – content of water, protein and fat, water-holding capacity, pH and shear force were determined

Water-holding capacity (WHC) was estimated by determining expressible juice using modification of the filter paper press method described by Wiebicki and Deatherage [1958]. The WHC was calculated as the fraction of water retained by the meat (expressible juice / total moisture content) – Allen *et al*. [1998].

To determine shear force a Texture Analyzer and a Warner-Bratzler device (C-LM_2, Northeast Agric Univ. Ltd., China) were used. Muscle samples were stored at 4°C for 24 h and were then individually cooked in a water bath at 80°C in plastic bags to an internal temperature of 70°C. Next, the samples were removed and chilled to room temperature. Strips (1.0×0.5×2.5 cm) parallel to the muscle fibres were prepared from the medial portion of the meat, and sheared vertically [Molette *et al*. 2003]. Shear force was expressed in kilograms.

The ultimate pH values of both *pectoralis* muscles were determined 45 min *post mortem*, using a portable pH meter (IQ150, IQ SCIENTIFIC INSTRUMENTS Inc., Carlsbad, CA, USA) equipped with an insertion glass electrode (pH57-SS). Before measurement, the electrode was calibrated using three buffers with pH of 4.01, 7.00 and 9.01. The samples' pH was always measured at the same place of the muscle. The mean pH value was obtained from three measurements of the same muscle sample.

Water, protein (nitrogen) and fat contents of feed and muscles were determined according to AOAC [1990].

Statistical

Data were processed by one-way ANOVA (SPSS Inc., 1993). When appropriate, differences among system means were compared with Duncan multiple-range test and were considered significant at $P < 0.05$.

Results and discussion

Growth rate and feed conversion

Effect of raising system on growth rate is shown in Figure 1 and Table 2. The body weight and weight gain of chicks in the free-range system were both lower than in the indoor-floor system ($P<0.05$), while those of chicks in the indoor-net system did not

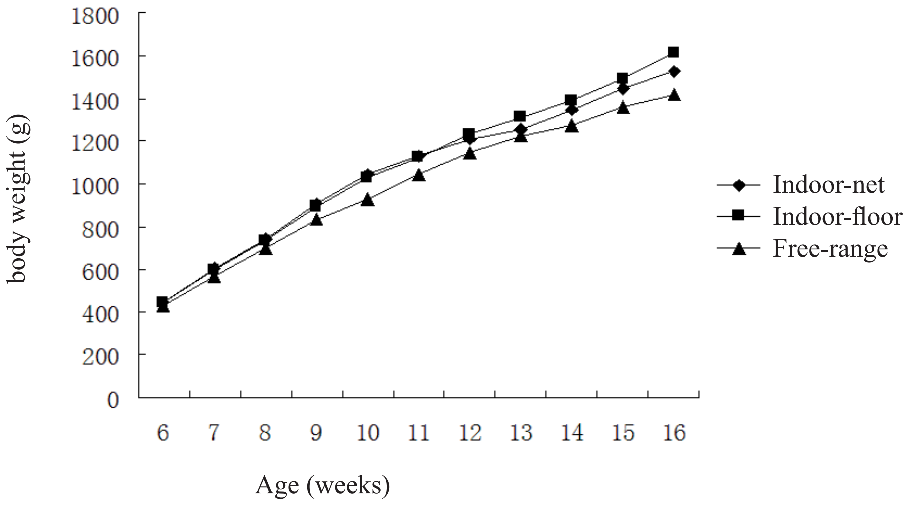

Fig. 1. Mean body weight of chicken.

Table 2. Effect of three raising systems on growth rate and feed conversion ratio in chicken[1]

Raising system		Final body weight(g)	Body weight gain (g)	Feed/gain ratio (g/g)
Indoor-net	mean	1528.52^{ab}	1174.81^{ab}	4.05^{ab}
	SD	123.14	78.92	0.27
Indoor-floor	mean	1610.51^{a}	1256.80^{a}	3.95^{b}
	SD	138.62	94.43	0.29
Free range	mean	1419.43^{b}	1065.74^{b}	4.41^{a}
	SD	101.80	57.62	0.43

[1]Three replicates within the system, 15 birds per replicate.
[ab]Within columns means bearing different superscripts differ significantly at P<0.05.

differ significantly from both indicators reached in the other two systems. The feed conversion (feed/gain) ratio in the free-range system showed similar trend, but the difference was higher than in birds from the indoor-floor system (P<0.05). Within the free-range system there are many not controllable and inherently variable factors, such as temperature, photoperiod, and light intensity that affect the results. Furthermore, birds have access to pasture with various forages, insects and worms. It was expected, that the performance of birds in a free-range system would be inferior to that of birds in a more controlled environment because the former would be exposed to fluctuating temperature and increased exercise on paddocks, increasing their energy demands with consequent increase in the use of feed for body weight gain. This was also shown in the current study. Castellini *et al*. [2002] reported growth rate and feed efficiency in outdoor organic rearing to be worse than in conventional rearing system. It was, however, contrary to the result by Santos *et al.* [2005] who demonstrated that body weight gain of broiler chicken in the confined system was lower than in the semi-confined system, due to unimproved bird comfort and welfare.

The birds in the indoor-net system also did more exercise than indoor-floor system birds due to the net, which needed more energy to keep balance when standing. But compared to outdoor system, the physical effort was limited. So the birds in the indoor-net system showed medium body weight and feed conversion ratio.

Carcass traits and tibia strength

Effects of raising systems on carcass traits are shown in Table 3. Although stocking density was lower in the free-range system, no impact of production system on eviscerated carcass, breast and thigh meat percentage (P>0.05) was identified, being in accordance with Fanatico *et al* [2005b]. In contrast, Ricard [1977] and Castellini *et al*. [2002] found that breast and thigh meat content of carcass both increased when birds had access to outdoor space and their stocking density was lower in an organic production system (forcing the locomotor activity).

The abdominal fat percentage of carcass in the free-range system was lower than in the indoor-floor and indoor-net systems (P<0.05). The intensive locomotor activity reduced the abdominal fat content and favoured muscle mass development, being in accordance with Ricard [1977], Lewis *et al*. [1997] and Castellini *et al*. [2002].

The birds raised in the free-range system grew heavier stomach (in relation to eviscerated carcass weight) than those in the indoor-floor and indoor-net systems (P<0.05). The birds of that group had access to grassy paddock and could intake various forages, insects, as well as sand particles. The crude fibre content of the former was significantly higher than that of commercial diets fed to the birds in the indoor system, which could stimulate the development of the stomach.

Free-range raising system significantly affected the bone-breaking strength, which was indicated by the more tender tibias of the free-range birds than birds from the indoor-floor and indoor-net systems (P< 0.05). This, however, differs from the results of Lewis *et al*. [1997] and Fanatico *et al*. [2005b], who claimed that the lower density of birds and intensive exercise in outdoor systems led to stronger bones. In the present study, more tender tibias in the free-range birds would be ascribed to the operation scale (large or small) and period, much higher requirement for calcium in free-range system, calcium level of the diet *etc*.

Table 3. Effect of three raising systems on carcass traits and tibia strength in chicken[1]

Raising system		Eviscerated carcass (%)[2]	Breast (%)[3]	Thigh (%)[3]	Abdominal fat (%)[3]	Stomach (%)[3]	Tibia strength (kg)
Indoor-net	mean	69.65^{a}	18.89^{a}	27.96^{a}	6.28^{a}	2.08^{b}	4.81^{a}
	SD	2.91	2.92	1.76	2.98	0.43	1.01
Indoor-floor	mean	69.90^{a}	17.44^{a}	26.68^{a}	6.50^{a}	1.70^{b}	5.04^{a}
	SD	2.04	2.92	0.50	3.19	0.20	0.88
Free-range	mean	69.88^{a}	20.17^{a}	27.65^{a}	3.01^{b}	2.53^{a}	3.46^{b}
	SD	1.12	0.83	1.12	1.13	0.36	0.58

[1]Three replicates within the system, 15 birds per replicate.
[2]Per cent of live body weight.
[3]Per cent of eviscerated carcass weight.
[ab]Within columns means bearing different superscripts differ significantly at P<0.05.

Meat Quality

Effects of three raising systems on meat quality are presented in Table 4. The composition of the muscle (water, protein and fat) was not found affected by raising system (P>0.05). This is in accordance with Fanatico *et al.* [2005a] who reported that outdoor (free-range) production system had limited impact on dry matter and fat content of meat of slow-growing broilers (P>0.05). According to Gordon and Charles [2002] temperature fluctuations could cause variation in meat quality. Heat may increase fat content (especially abdominal) of carcass, and in cold temperature, less fat and meat are deposited. The present study was conducted in mild temperature that may have resulted in nutrient deposition similar in different production systems.

In this study, the WHC in free-range birds, did not differ from that found in indoor birds (P>0.05) – Table 4 – while Castellini *et al* [2002] and Fanatico *et al* [2007] found outdoor (free-range) production system resulting in lower WHC (P<0.05). Lower WHC indicates losses in the nutritive value through exudates that are released and result in drier and tougher meat [Dabes 2001].

No differences were identified among three raising systems in shear force of meat (P>0.05). This is in accordance with Fanatico *et al*. [2005a] who demonstrated that production system had no effect on tenderness of meat in the slow-growing broilers. However, Farmer *et al* [1997] observed the same tendency for breast meat from birds reared under a lower stocking density. Castellini *et al.* [2002] showed the production system to affect the shear force that was higher in either the breast or drumstick of the organic animals (P<0.05), presumably as a consequence of their greater locomotor activity.

Table 4. Effect of raising system on selected meat quality indicators in chicken[1]

Raising system		Water content of meat (%)	Protein content of meat (%)	Fat content of meat (%)	Water holding capacity (%)	Shear force (kg)	pH_{45}
Indoor-net	mean	71.92	24.09	0.53	52.73	3.19	5.6
	SD	0.48	0.38	0.08	4.75	0.66	0.09
Indoor-floor	mean	71.40	24.26	0.86	55.18	3.57	5.75
	SD	0.77	0.79	0.10	5.31	0.30	0.31
Free-range	mean	71.92	24.49	0.54	56.90	3.22	5.56
	SD	0.38	0.69	0.07	6.22	0.85	0.06

[1]Three replicates within the system, 15 birds per replicate.
Within columns no significant differences among means were identified.

High muscle pH results in shorter shelf-life of meat, especially as related to microbial growth. In the present report meat pH in both indoor systems was higher, although not significantly (P>0.05), than in free-range birds. It is in accordance with Fanatico *et al.* [2007] who reported the latter system to result in lower pH of meat in slow-growing chicken (P<0.05). Exercise is likely to affect muscle metabolism as altered by the forage intake and stocking density [Farmer *et al*. 1997]. Culioli *et* *al*. [1990] and Castellini *et al.* [2002] found the similar relation while Alvarado *et al*. [2005] reported free-range raising system to result in higher pH of meat.

The results presented here show that free-range raising system of slow-growing chicken broilers had significant effect on growth rate of birds, but limited effect on their carcass traits and meat quality, except for abdominal fat and stomach content of carcass and tibia strength.

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Tempo wzrostu, cechy tuszy i jakość mięsa wolno rosnących kurcząt w trzech systemach utrzymania

S t r e s z c z e n i e

Kurczęta utrzymywano w budynkach z podłogą stałą, z podłogą z siatki oraz w systemie wolnym w budynkach, ale z dostępem do trawiastego wybiegu – odpowiednio system I, II i III. Obsada we wszystkich systemach wynosiła 7 ptaków/m2, a systemie III na jednego ptaka dodatkowo 1m2. Badania prowadzono przez 112 dni, stosując jednakową paszę, a następnie ptaki ubito. Masa ciała i przyrosty w systemie III okazały się istotnie niższe niż w I, podczas gdy zużycie paszy na przyrost kształtowało się odwrotnie. Nie stwierdzono różnic między systemami utrzymania w masie tuszy oraz masie mięśni mostka i nóg wyrażonej jako procent tuszy. Stwierdzono wpływ systemu utrzymania na udział tłuszczu wewnętrznego i masy żołądka w masie tuszy i na kruchość kości. System utrzymania nie wpływał istotnie na zawartość wody, białka i tłuszczu, jak również na zdolność utrzymywania wody własnej, siłę cięcia i pH mięsa.