Effects of different raising systems on growth performance, carcass, and meat quality of medium-growing chickens

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ABSTRACT

A growing awareness of human health, nutrition, and animal welfare concerns has led to the development of specialty markets for organic food. Poultry produced in alternative systems, such as free-range or organic, are part of this trend. The aim of the present study was to evaluate the differences in growth performance, carcass traits, and meat quality of medium-growing chickens raised in three different raising systems: indoor-floor, cage, and free-range. One hundred and twenty female Lingnanhuang medium-growing birds were reared in each system. All birds were offered the same diets and were grown for 90 days. The body weight gain and feed conversion ratios (feed/gain) of birds from the cage and indoor-floor systems were superior to those kept in the free-range system. The raising system significantly affected eviscerated carcass, abdominal fat, breast muscle, and leg muscle yields as well as shear force value of muscle \((P < .05)\). There was no difference in pH, water-holding capacity, intramuscular fat, and inosine monophosphate content among the systems \((P > .05)\). In conclusion, in medium-growing chickens, the free-range raising system had significant negative effects on growth performance and abdominal fat content.

1. Introduction

Human health, nutrition, and animal welfare are increasingly attracting consumer attention and organic food markets are becoming more popular. Poultry products, which are an important food source worldwide, are similarly experiencing growth in the organic market. Many consumers believe that poultry rearing using conventional confinement systems leads to animal stress, resulting in negative physiological and behavioural responses and poor performance. In contrast, outdoor raising systems could improve bird growth condition and decrease stress (Mikulski et al. 2011). In addition, outdoor production systems allow selection of strains that may increase comfort and bird welfare. Many consumers prefer to buy products from chickens raised outdoors (free range) because they believe that these products have superior sensory qualities or, in other words, taste better (Yang et al. 2015). This perception has been confirmed by Fanatico et al.; in 2006 they found that an outdoor (free range) raising system improved the flavour of chicken meat. The same group also showed significantly different growth rates among chickens of different genotypes when they were reared with or without outdoor access (Fanatico et al. 2005). In contrast, Mikulski et al. reported in 2011 that body weight (BW) and meat yield and quality of chickens was primarily due to genotype, and outdoor access did not negatively affect their growth performance or meat yield. Certainly, a multitude of factors, including genotype, age, sex, diet, density, environment, exercise, and pasture intake, impact the growth and performance of specialty birds (Gordon & Charles 2002). In the current study, we reared broilers of the same genotype in three different raising systems in order to evaluate the effects of raising system on their growth performance, carcass traits, and meat quality.

2. Materials and methods

2.1. Ethics statement

This study was approved by the Animal Care Committee of the Institute of Animal Science, Guangdong Academy of Agricultural Sciences (Guangzhou, People’s Republic of China).

2.2. Experimental design and bird management

A total of 400 one-day-old female Lingnanhuang (LNH) chicken, a medium-growing commercial broiler, which were provided by the Guangdong WIZ Agricultural Science & Technology Co. Ltd. (Guangzhou, China), and reared in an indoor pen until 29 d of age. At 29 d, 360 female birds with similar BWs were randomly assigned to one of three raising systems (free-range, cage, and indoor-floor), each of which had three replicates of 40 birds (i.e. a total of 120 birds per system). Birds in the indoor-floor system were raised in solid-floored pens in a conventional poultry research house with side curtains and fans for ventilation and cooling. The density of each pen was 8 birds/m\(^2\), the temperature was 20 ± 3°C, the relative humidity was 60–70%, and the
photoperiod was 12 h. The cage raising system is typically used in the Chinese broiler industry, applied in the present study with 3 birds in each cage and each cage measuring 90 cm × 45 cm × 50 cm in size (7.4 birds/m²). The birds in the free-range system were raised in a similar indoor house but they also had free daytime (from 06:00 to 18:00) access to a grass paddock and kept indoor during the night. A total of 40 birds (0.98 m²) were raised in each outdoor yard (8.5 × 4.7 m). The grass paddock were partly (~40%) covered with native grass of Gramineae, Compositae such as *Setaria viridis* Beauv, *Artemisia argyi* Levil, and *Mimosa pudica* Linn and shade available which provided both feed resources and habitat for the chickens. Additional feed and water were also provided outdoors using trough feeders and water pans with reservoirs. The experiment was conducted from April to June, at experimental farm of Institute of Animal Science, Guangdong Academy of Agricultural Sciences (113°17′ East, 23°8′ North, 43.4 m above sea level) in Guangzhou, China. During the trail, the average daily outdoor temperature ranged between 21°C and 30°C, which was quite suitable for these birds, and total precipitation was 768 mm. All birds were offered the same feed and water ad libitum (Table 1) and were feed and vaccinated according to the company’s management guide until 90 d of age.

### 2.3. Sampling and analyses

Broiler's BW were individually recorded at 29 and 90 d of age and provided and residual feed was weighed daily for each replicate in per pen in order to determine feed intake and feed efficiency. At 90 d of age, all birds were fasted for 10 h, individually weighed, and then slaughtered by manual exsanguination. After exsanguination and removal of the feathers, the eviscerated carcass, abdominal fat, breast meat (pectoralis major and pectoralis minor), and leg meat (thigh and drumstick) were weighed. The eviscerated carcass percentage was calculated as the ratio between the eviscerated carcass weight and live BW after fasting. The weight percentages of breast meat, leg meat, and abdominal fat were calculated as percentages of the eviscerated carcass weight.

Samples collected from the left side of the pectoralis major muscle were used for meat quality analysis. Physicochemical characteristics of the breast muscle samples, such as pH, water-holding capacity (WHC), shear force, intramuscular fat (IMF), and inosine monophosphate (IMP) content, were evaluated. The ultimate pH values of the pectoralis muscles were measured 45 min postmortem using a portable pH meter (IQ150, IQ Scientific Instruments Inc., Carlsbad, CA) according to the manufacturer’s instructions. The WHC was estimated by determining expressible juice using a modification of the filter paper press method described by Wiebicki and Deatherage (1958). Warner-Bratzler shear force was determined by using an Instron Universal Mechanical Machine (Instron model 4411, Instron Corp., Canton, MA). The IMF content of the breast meat was determined using the Soxhlet extractor method (Zhao et al. 2008; Ren et al. 2011). The IMP content was measured using high-performance liquid chromatography as described by Zhang et al. (2004).

### 2.4. Statistical analysis

Data were analysed by GLM (SAS Institute, 2003) using the following model:

\[ Y = \mu + S + W + e, \]

where \( Y \) represented the dependent variable of test trait such as eviscerated carcass, abdominal fat, \( \mu \) is the population mean, \( S \) is the fixed effect of raising system, \( W \) is the covariance of BW at 29 days old, and \( e \) is the residual random error. When appropriate, differences among group means were compared using Duncan’s multiple range tests. Between-group differences were considered statistically significant at \( P < .05 \). Data are reported as means ± standard deviation.

### 3. Results and discussion

#### 3.1. The effects of raising system on growth performance

The feed intake, BW gain, and feed conversion of the chickens in each of the three raising systems are shown in Table 2. The feed intake of chickens in the cage group was significantly higher than that of the chickens in the free-range and indoor-floor groups (\( P < .05 \)). The chickens in the free-range group had the lowest feed intake. Birds in the cage group gained more BW than those in the free-range group (\( P < .05 \)) and had a better feed/gain ratio than the birds in either of the other groups (\( P < .05 \)). These differences may be explained by the inherent variability in free-range raising systems; free-range birds are exposed to some factors that are inherently variable, such as light intensity, photoperiod, and temperature. Furthermore, birds raised in a free-range system have access to the various forages, insects, and worms found on pasture; these may contribute some dietary nutrients and thus interfere with their normal intake of commercial feed. As was expected, the growth performance of birds in the free-range raising system was inferior to that of birds raised in more controlled environments; this is likely because the free-range birds were exposed to fluctuating temperatures and increased exercise in the yards, thus increasing their energy requirement and influencing their feed conversion. Similar results have been reported previously; for example, in 2002 Castellini et al. demonstrated that growth rates and feed efficiencies were lower in outdoor organic raising systems than in other (conventional) systems. Since then there has been much researchers examined the influence of different production systems on the growth performance of birds. Wang et al. (2009) found that BWs and weight gains of Gushi female chickens in a free-range raising system were much lower than those of chickens raised in indoor solid-floored pens. Dou et al. (2009) also found that a free-range raising system for chickens negatively influenced

### Table 1. Nutrient and energy content of the feeds.

| Item                        | 1d to 28d | 29d to slaughter |
|-----------------------------|-----------|------------------|
| Metabolizable energy (MJ/kg)| 12.12     | 12.96            |
| Crude protein (%)           | 21.98     | 20.19            |
| Crude fat (%)               | 3.19      | 6.19             |
| Calcium (%)                 | 1.00      | 0.93             |
| Available phosphorus (%)    | 0.60      | 0.57             |
BW, weight gain, and feed conversion ratio (feed/gain). The results of our current study are also similar to those of previous studies analysing the effects of different feeding methods on the growth of local breeding, including the Tibet chicken, Liyang chicken, and Guinea fowl (Li et al. 2011; Wan et al. 2011; Liu 2012). However, some studies have demonstrated that the growth performance of chickens was not affected by their outdoor access, possibly due to relatively less exercise of the free-range group (the pasture was removed) (Chen et al. 2013); and perhaps owing to increased exercise of the indoor-floor group (the deep litter was provided) (Sogunle et al. 2012).

### 3.2. The effects of raising system on carcass characteristics

The mean eviscerated carcass, fat, breast, and leg muscle yields of chickens in each of the three raising systems are shown in Table 3. The eviscerated carcass percentage of chickens in the indoor-floor group was significantly greater than that of chickens in the cage group (P < .05), while the mean eviscerated carcass percentage of the free-range chickens was not significantly different from that of either of the other groups. Similar findings have been reported by Fanatico et al. (2005), Wang et al. (2009), and Chen et al. (2013). In contrast, Castellini et al. (2002) and Feddes et al. (2002) stated that the eviscerated carcass percentage significantly increased when birds had outdoor access because of increased motor activity. The abdominal fat yield of chickens in the free-range system was significantly lower than that of chickens in both the indoor-floor and cage groups (P < .05), which was also consistent with the results of previous studies (Castellini et al. 2002; Wang et al. 2009; Jiang et al. 2011). This may be due to the environmental conditions in the outdoor paddock, which could have increased the birds’ metabolic rates and use of fat and energy, with a consequent reduction in abdominal fat deposition. However, Mikulski et al. (2011) and Chen et al. (2013) found that outdoor access had no effect on the abdominal fat ratio, which possibly due to fluctuation of environment temperature (mean of highest temperatures 29.8°C and of the minimum 8.7°C) and reduction of motion of the free-range group (the pasture was removed). For instance, heat may increase abdominal fat, and less fat and meat are deposited in cold temperatures. The present study was conducted in mild temperatures, which may account for the similar parts yield between production systems. Increased physical activity has been shown to reduce abdominal fat and favour muscle mass development (Castellini et al. 2002). In the current study, we found that both breast and leg muscle yield were influenced by the production system (Table 3). The highest breast muscle yield was found in the indoor-floor group, but the highest leg muscle yield was found in the cage group. However, a significant distinction between the free-range and the two traditional systems was not found. Fanatico et al. (2005), Wang et al. (2009), Jiang et al. (2011), Mikulski et al. (2011), and Chen et al. (2013) all similarly demonstrated a lack of significant differences in meat yield between conventionally and free-range raised birds; however, Castellini et al. (2002) and Feddes et al. (2002) found that the breast and leg meat percentages increased, likely because of greater physical activity, when birds had outdoor access and a lower stocking density in an organic production system.

There are several key factors that have been inconsistent among studies on the effects of different raising systems on bird performance. Although stocking density is universally acknowledged to affect bird performance, with poorer performance at higher stocking densities, the stocking densities used in previous studies have been highly variable. Feddes et al. (2002) demonstrated that birds grown at a stocking density of 23.8 birds/m² had lower BW than birds grown at 14.3 birds/m², thus different stocking densities may influence results. Also, weather conditions and temperature differ between out- and indoor systems. Both temperature and photoperiod have the potential to influence growth, mainly by affecting feed intake. Feed intake is increased at cold temperatures and reduced at hot temperatures (Gordon & Charles 2002). Thus, it can be difficult to differentiate between production and meat quality differences due to various rearing systems and differences owing to specific variations that occur within those systems.

### 3.3. The effects of raising system on meat quality

The effects of the three raising systems on meat quality are presented in Table 4. Shear force (tenderness) represents the ease with which the muscle is chewed or cut and is one of the most important sensory characteristics of meat, it is a crucial factor for consumers. The shear force of the meat was significantly affected by the raising system, with chickens in the cage group having a significantly lower muscle shear force relative to that of chickens in the indoor-floor group (P < .05), and having a lower muscle shear force relative to that of chickens in the free-range group (P > .05). This is similar to the findings of Castellini et al. (2002), who reported that the breast muscle

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**Table 2. Effect of three different raising systems on growth performance.**

| Raising system | Final weight (g) | Feed intake (g/d) | BW gain (g/d) | Feed/gain ratio (g/g) | Mortality (%) |
|----------------|-----------------|------------------|--------------|-----------------------|--------------|
| P-value        |                 |                  |              |                       |              |
| Free-range     | 4.03 x 10⁻⁷     | 8.12 x 10⁻³      | 1.69 x 10⁻³  | 0.037                 | /            |
| Cage           | 2089.47 ± 36.46b| 98.67 ± 1.32b    | 30.5 ± 1.03b | 3.24 ± 0.20b          | 0.8          |
| Indoor-floor   | 2142.00 ± 40.15b| 111.45 ± 0.98b   | 36.3 ± 1.24b | 3.07 ± 0.22b          | 0.8          |

Note: Within-column means bearing different superscripts (a,b) differ significantly (P < .05).

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**Table 3. Effect of three different raising systems on carcass yield.**

| Raising system | Eviscerated carcass (%) | Abdominal fat (%) | Breast muscle (%) | Leg muscle (%) |
|----------------|-------------------------|------------------|------------------|---------------|
| Free-range     | 68.47 ± 1.13ab          | 5.26 ± 0.62ab    | 17.98 ± 1.26ab   | 19.76 ± 1.61ab|
| Cage           | 67.78 ± 1.79b           | 7.18 ± 0.98ab    | 17.05 ± 1.70b    | 20.32 ± 1.37ab|
| Indoor-floor   | 69.08 ± 1.49b           | 7.56 ± 0.69ab    | 18.89 ± 1.85ab   | 19.17 ± 1.27ab|

Note: Within-column means bearing different superscripts (a,b) differ significantly (P < .05).
shear value was higher in organic animals. In contrast, other studies have failed to find a significant effect of raising system on shear force (Fanatico et al. 2005; Wang et al. 2009). Differences in muscle shear force are presumably a consequence of variations in physical activity; however, in previous studies the activity space or yard size of birds in free-range systems have differed greatly, ranging from as much as 4 m²/bird to as little as 1 m²/bird.

Muscle pH is significant in terms of preservation and stability of meat; a high muscle pH results in shorter shelf life stability, especially as it pertains to microbial growth. The postmortem decline in pH is one of the most important events in the conversion of muscle to meat due to its effect on meat tenderness, colour, and WHC (Aberle et al. 2001). We found that pH was not affected by the raising system. Wang et al. (2009) and Fanatico et al. (2007) also reported that muscle pH was largely unaffected by a free-range system. The WHC is closely related to the loss of nutritive value from whole meat and further-processed meat products through exudates, and poor WHC results in dry and tough meat (Wang et al. 2009). The WHC did not differ among the groups in our study (P > .05), Wang et al. (2009) found a similar result. It was consistent with the muscle pH measuring result, because glycogen concentration in muscle was key factor of postmortem pH decline, and was strong negative genetic correlation (rg) with ultimate pH (rg = −0.97). Furthermore, pH of the meat was the key factor of chicken meat quality and low final pH reduced WHC (Berri et al. 2005; Le Bihan-Duval et al. 2008).

The IMF content is an important determinant of meat quality (flavour and juiciness) and plays a critical role in consumer acceptance of chicken meat (Zhao et al. 2007; Yang et al. 2015). IMF is a flavour precursor and is used in conjunction with the flavour enhancer monosodium glutamate (Vani et al. 2006). IMF is the major nucleotide in muscle and its degradation results in the formation of ribose in meat, which is important for the Maillard reaction (Lee et al. 2015). There were no significant differences in IMF or IMP among the different production systems (P > .05), which is in agreement with previously reported results (Fanatico et al. 2007; Xu et al. 2012). However, some studies have reported lower IMF in free-range birds due to the effects of increased activity on energy balance and lipid metabolism (Yang et al. 2009, 2015).

4. Conclusion

Our results indicate that raising systems have a significant effect on growth performance, carcass traits, and the shear force of meat in medium-growing chickens. The free-range raising system negatively affects growth performance and abdominal fat content due to more activity, however, relative lower fat deposition is an advantage and appropriate for gourmet market in China. The free-range raising system is an alternative production strategy that may appeal to purchasers in a special markets (for high meat quality demand) and is also a low cost production system in breed facility that suit to the small scale of individual breeding in developing country.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Table 4. Effect of three different raising systems on meat quality.

| Raising system | pH    | WHC (%) | Shear force (kg) | IMF (%) | IMP (mg/g) |
|----------------|-------|---------|------------------|--------|-----------|
| Free-range     | 5.90 ± 0.07a | 78.16 ± 1.62a | 3.55 ± 0.32bc | 2.92 ± 0.26a | 3.56 ± 0.16a |
| Cage           | 5.79 ± 0.08a | 75.35 ± 1.74a | 2.73 ± 0.35c  | 3.02 ± 0.27a | 3.64 ± 0.17a |
| Indoor-floor   | 5.84 ± 0.07b | 77.72 ± 1.61a | 4.26 ± 0.32ab | 2.76 ± 0.26a | 3.55 ± 0.16a |

Note: Within-column means bearing different superscripts (a,b) differ significantly (P < .05).
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