Effects of Dietary Nutrient Levels on Growth Performance, Carcass Quality, Meat Quality, Flavor, and Plasma Biochemical Indices in Medium-Growing Yellow-Feathered Broilers (Postprint)

Authors: Lin Xiajing, Gou Zhongyong, Li Long, Huang Danhong, Fan Qiuli, Jiang Shouqun

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Abstract

This experiment aimed to investigate the effects of dietary nutrient levels on growth performance, carcass quality, meat quality, flavor, and plasma biochemical indices in medium-speed yellow-feathered broilers. A total of 1,920, 1,920, and 1,440 medium-speed Lingnan yellow-feathered broilers (half male and half female) at 1, 29, and 57 days of age were selected, respectively. The experiment was divided into three phases, with each phase establishing a low nutrient level group, a medium nutrient level group, and a high nutrient level group based on the feeding standard for yellow-feathered broilers proposed by our research group, along with a standard nutrient level group based on China' s "Feeding Standard of Chicken" (NY/T 33–2004). Each group had 6 replicates for males and 6 replicates for females, with 30-40 birds per replicate. The experimental period lasted 84 days. The results showed that: 1) At 1-28 days of age, for males, the high nutrient level group had significantly higher average daily gain (ADG) than the low and medium nutrient level groups ($P < 0.05$), and both the high nutrient level group and standard nutrient level group had significantly higher average daily feed intake (ADFI) than the low and medium nutrient level groups ($P < 0.05$), while the low nutrient level group had significantly higher feed conversion ratio (FCR) than the other nutrient level groups ($P < 0.05$); for females, the low nutrient level group had significantly lower ADG than the other nutrient level groups ($P < 0.05$), the standard nutrient level group had significantly higher ADFI than the low nutrient level group ($P < 0.05$), and the medium nutrient level group had significantly lower FCR than the low nutrient level group ($P < 0.05$). At 29-56 days of age, for males, the low nutrient level group had significantly higher FCR than the other nutrient level groups (P <

0.05); for females, the low nutrient level group had significantly lower ADG than the other nutrient level groups ($P < 0.05$), the medium and standard nutrient level groups had significantly higher ADFI than the high nutrient level group ($P < 0.05$), and the low nutrient level group had significantly higher FCR than the high and standard nutrient level groups ($P < 0.05$). At 57–84 days of age, the high nutrient level group had significantly higher ADG for both males and females than the standard nutrient level group ($P < 0.05$), and the high nutrient level group had significantly lower FCR for females than the other nutrient level groups ($P < 0.05$). 2) The standard nutrient level group had significantly lower abdominal fat percentage in females than the high nutrient level group ($P < 0.05$). Dietary nutrient levels had no significant effect on dressing percentage, semi-eviscerated yield, eviscerated yield, leg muscle percentage, breast muscle percentage, or tibia breaking strength in either males or females ($P > 0.05$). 3) The high nutrient level group had significantly higher 45-min meat color b* value in males than the low and standard nutrient level groups ($P < 0.05$). Dietary nutrient levels had no significant effect on muscle tenderness, drip loss, or pH in males ($P > 0.05$). Dietary nutrient levels had no significant effect on any meat quality indices in females ($P > 0.05$). 4) Dietary nutrient levels had no significant effect on flavor indices in breast muscle of either males or females ($P > 0.05$). 5) Dietary nutrient levels had no significant effect on calcium, uric acid, or urea nitrogen contents in plasma of either males or females ($P > 0.05$). Based on the comprehensive results of growth performance, cost per unit gain, carcass quality, meat quality, and plasma biochemical indices in this experiment, it is recommended that medium nutrient level diets be used for both males and females at 1–28 days of age; medium nutrient level diets be used for both males and females at 29–56 days of age; and high nutrient level diets be used for both males and females at 57–84 days of age.

Full Text

Effects of Dietary Nutrient Level on Growth Performance, Carcass Quality, Meat Quality, Flavor and Plasma Biochemical Parameters of Medium-Growing Yellow-Feathered Broilers

LIN Xiajing, GOU Zhongyong, LI Long, HUANG Danghong, FAN Qiuli, JIANG Shouqun*

(Institute of Animal Science, Guangdong Academy of Agricultural Sciences, State Key Laboratory of Livestock and Poultry Breeding, Key Laboratory of Animal Nutrition and Feed Science in South China, Ministry of Agriculture, Guangdong Public Laboratory of Animal Breeding and Nutrition, Guangdong Key Laboratory of Animal Breeding and Nutrition, Guangzhou 510640, China)

Abstract

This experiment was conducted to investigate the effects of dietary nutrient level on growth performance, carcass quality, meat quality, flavor and plasma biochemical parameters of medium-growing yellow-feathered broilers. A total of 1,920, 1,920 and 1,440 medium-growing Lingnan yellow-feathered broilers at 1, 29 and 57 days of age were selected, respectively. The experiment was divided into three stages, with four dietary treatments at each stage: low, medium, and high nutrient level groups (based on our research group' s proposed standards for yellow-feathered broilers, adjusted by decreasing or increasing energy by 5% and other nutrients by 10%) and a standard nutrient level group based on China' s *Standard of Chicken Feeding* (NY/T 33—2004). Each group consisted of six replicates for males and six for females, with 30-40 birds per replicate. The experimental period lasted 84 days.

The results showed: 1) During days 1-28, male broilers in the high nutrient level group exhibited significantly higher average daily gain (ADG) than those in the low and medium groups ($P<0.05$), while both the high and standard groups showed significantly higher average daily feed intake (ADFI) than the low and medium groups ($P<0.05$). The feed-to-gain ratio (F/G) of the low nutrient group was significantly higher than all other groups ($P<0.05$). For females, the low nutrient group had significantly lower ADG than other groups ($P<0.05$), the standard group showed significantly higher ADFI than the low group ($P<0.05$), and the medium group had significantly lower F/G than the low group ($P<0.05$).

During days 29-56, male broilers in the low nutrient group had significantly higher F/G than other groups ($P<0.05$). For females, the low nutrient group showed significantly lower ADG than other groups ($P<0.05$), while the medium and standard groups had significantly higher ADFI than the high group ($P<0.05$). The F/G of the low nutrient group was significantly higher than that of the high and standard groups ($P<0.05$).

During days 57-84, both male and female broilers in the high nutrient group demonstrated significantly higher ADG than the standard group ($P<0.05$), and females in the high nutrient group had significantly lower F/G than all other groups ($P<0.05$).

2) The abdominal fat rate of female broilers in the standard nutrient group was significantly lower than that of the high nutrient group ($P<0.05$). Dietary nutrient level had no significant effects on carcass rate, half-eviscerated rate, eviscerated rate, leg muscle rate, breast muscle rate, or tibia breaking force in either sex ($P>0.05$).

3) The 45-min meat color b* value of male broilers in the high nutrient group was significantly higher than that of the low and standard groups ($P<0.05$). Dietary nutrient level showed no significant effects on tenderness, drip loss, or pH of male broilers ($P>0.05$), and no significant effects on any meat

quality parameters of female broilers (P>0.05).

4) Dietary nutrient level had no significant effects on flavor indices of breast muscle in either male or female broilers (P>0.05).
5) Dietary nutrient level showed no significant effects on plasma calcium, uric acid, or urea nitrogen contents in either sex (P>0.05).

Based on comprehensive evaluation of growth performance, weight gain cost, carcass quality, meat quality and plasma biochemical indices, we recommend medium nutrient level diets for both sexes during days 1-28 and 29-56, and high nutrient level diets during days 57-84.

Keywords: yellow-feathered broilers; meat quality; flavor; nutrient level

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Yellow-feathered broilers represent a distinctive sector of China' s poultry industry, with annual slaughter volumes now comparable to those of white-feathered broilers. In 2017, commercial yellow-feathered broiler slaughter reached 4.33 billion birds, with Guangdong Province accounting for 70% of the national production. Therefore, rational feed formulation to improve feed conversion efficiency is crucial for reducing production costs of Lingnan yellow-feathered broilers. Li et al. [1] reported that increased nutrient levels effectively improved the apparent digestibility of energy, crude protein, crude fat, and crude fiber in Guixiang chicks. Miah et al. [2] found that higher dietary nutrient levels increased profit margins for indigenous chicken breeds in Bangladesh. Sun [3] demonstrated that high nutrient levels improved carcass quality, while other studies reported that low nutrient levels decreased slaughter performance [4]. Previous research on dietary nutrient levels in local breeds has focused primarily on males and energy-protein aspects, with limited investigation of complete nutrient requirements and female responses.

Our research team has long studied the nutritional requirements of yellow-feathered broilers, investigating needs for protein and energy [5], calcium [6], phosphorus [7], zinc [8], sodium and chloride [9], lysine [10], methionine [11], threonine [12], tryptophan [13], isoleucine [14], and vitamins A, D3, E, and B2 [15-18]. Based on accumulated data, we established nutrient requirement parameters for both male and female yellow-feathered broilers. This experiment validates these parameters by evaluating growth performance, carcass quality, meat quality, flavor, and plasma biochemical indices in medium-growing yellow-feathered broilers to determine optimal dietary nutrient levels, providing scientific guidance for production and economic benefits for feed companies and farmers.

1.1 Experimental Animals and Design

The experiment was conducted in three independent phases. For days 1-28, 1,920 one-day-old yellow-feathered broilers were selected (six male replicates and six female replicates, 40 birds per replicate). For days 29-56, 1,920 29-day-old broilers were selected (six male and six female replicates, 40 birds per replicate). For days 57-84, 1,440 57-day-old broilers were selected (six male and six female replicates, 30 birds per replicate).

Each phase included four dietary treatment groups: low, medium, and high nutrient level groups (based on our research group' s proposed standards, adjusted by ±5% energy and ±10% other nutrients) and a standard nutrient level group based on China's *Standard of Chicken Feeding* (NY/T 33-2004). A corn-soybean meal basal diet was formulated according to the *Chinese Feed Composition and Nutritional Value Tables* (15th edition). Dietary composition and nutrient levels for males and females are presented in and , respectively.

1.2 Management

Birds were raised on floor with ad libitum access to pelleted feed and water. During days 1-28, room temperature was maintained at 32°C with 24-hour continuous lighting (natural daylight supplemented by artificial light at night). During days 29-56 and 57-84, birds were housed in open-sided sheds with natural lighting only. Conventional management and immunization protocols were followed.

1.3.1 Growth Performance

At the beginning and end of each phase, feed was withdrawn at 22:00 while water remained available. At 09:00 the following day, body weight and residual feed were measured by replicate to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G). Weight gain cost was estimated based on current market prices of feed ingredients.

1.3.2 Plasma Biochemical Indices

At the end of each phase (days 28, 56, and 84), two birds per replicate (one male and one female) with body weight close to the replicate average were selected for blood collection. Plasma was prepared and stored at -20°C for analysis. Plasma calcium, uric acid, and urea nitrogen contents were determined using a Beckman automatic biochemical analyzer (CX5 model, Beckman Instruments, USA) with corresponding reagent kits (Nanjing Jiancheng Bioengineering Institute, China) following the manufacturer' s instructions.

1.3.3 Carcass Quality and Tibia Breaking Force

At the end of phase 3 (day 84), two birds per replicate (one male and one female) with body weight close to the replicate average were selected, weighed, and processed. Carcass rate was determined after feather, foot skin, toe nail, and beak removal. Half-eviscerated rate was calculated after removal of trachea, esophagus, crop, intestines, spleen, pancreas, gallbladder, and reproductive organs.

Eviscerated rate was determined after additional removal of heart, liver, glandular stomach, gizzard, fat, head, and feet, while retaining heart, liver, kidneys, glandular stomach, gizzard (with cuticle and contents removed), abdominal fat, gizzard fat, lungs, and kidneys. Breast muscle, leg muscle, and abdominal fat (including gizzard fat) were separated and weighed to calculate muscle and fat percentages based on carcass weight.

Tibia breaking force was measured at day 84 using two birds per replicate (one male and one female) with body weight close to the replicate average. The left tibia was extracted intact, surface membranes removed, and breaking strength immediately measured using a testing machine (INSTRON 4411, Instron, USA).

1.3.4 Meat Quality

At day 84, two birds per replicate (one male and one female) with body weight close to the replicate average were selected. Skinless, boneless breast muscles were excised and surrounding fat removed for determination of pH, meat color, tenderness, and drip loss.

Meat color: Lightness (L*), redness (a*), and yellowness (b*) values were measured at three locations per sample using a colorimeter (CR-410, Minolta, Japan) at 45 min and 24 h post-mortem (stored at 4°C).

pH: Measured at three locations per sample using a pH meter (HI8424, Hanna Instruments, Beijing) at 45 min, 24 h, and 72 h post-mortem (stored at 4°C).

Drip loss: A approximately 2.0 g muscle sample was weighed, suspended in an inflated bag, stored at 4°C for 24 h, and reweighed. Drip loss (%) = [(pre-drip weight - post-drip weight) / post-drip weight] × 100.

Tenderness: Determined using the method of Jiang et al. [19] with a tenderness tester (Instron 4411, Instron, USA).

1.3.5 Flavor Evaluation

Breast muscle from each treatment bird (day 84) was cut into pieces, placed in small bowls covered with aluminum foil, and steamed for 20 minutes. All samples were coded numerically to conceal treatment identity. Twelve poultry experts evaluated color/shape, aroma, flavor, tenderness, juiciness, and breast muscle size using a 5-point scale, with water rinsing between samples. Mean scores were calculated for each attribute.

1.4 Statistical Analysis

All performance parameters for males and females were analyzed separately using SPSS 17.0 software. When significant differences were detected, Duncan's multiple comparison test was applied. Significance was declared at $P<0.05$. Results are presented as means.

2.1 Effects of Dietary Nutrient Level on Growth Performance

As shown in , during days 1-28, male broilers in the high nutrient group exhibited significantly higher ADG than the low and medium groups (P<0.05), while the high and standard groups showed significantly higher ADFI than the low and medium groups (P<0.05). The F/G of the low nutrient group was significantly higher than all other groups (P<0.05), and weight gain cost of the low and medium groups was significantly lower than the high and standard groups (P<0.05). For females, the low nutrient group had significantly lower ADG than other groups (P<0.05), the standard group showed significantly higher ADFI than the low group (P<0.05), the medium group had significantly lower F/G than the low group (P<0.05), and weight gain cost of the low and medium groups was significantly lower than the high and standard groups (P<0.05).

During days 29-56, male broilers in the low nutrient group had significantly higher F/G than other groups (P<0.05), while weight gain cost of the high group was significantly higher than the low and standard groups (P<0.05). For females, the low nutrient group showed significantly lower ADG than other groups (P<0.05), the medium and standard groups had significantly higher ADFI than the high group (P<0.05), and the low group exhibited significantly higher F/G than the high and standard groups (P<0.05).

During days 57-84, both male and female broilers in the high nutrient group demonstrated significantly higher ADG than the standard group (P<0.05), and females in the high nutrient group had significantly lower F/G than all other groups (P<0.05).

2.2 Effects of Dietary Nutrient Level on Carcass Quality

As shown in , the abdominal fat rate of female broilers in the standard nutrient group was significantly lower than that of the high nutrient group (P<0.05), while no significant differences were observed among male groups (P>0.05). Dietary nutrient level showed no significant effects on carcass rate, half-eviscerated rate, eviscerated rate, leg muscle rate, breast muscle rate, or tibia breaking force in either sex (P>0.05).

2.3 Effects of Dietary Nutrient Level on Meat Quality

As shown in , the 45-min meat color b* value of male broilers in the high nutrient group was significantly higher than that of the low and standard groups (P<0.05). Dietary nutrient level showed no significant effects on tenderness, drip loss, or pH of male broilers (P>0.05), and no significant effects on any meat quality parameters of female broilers (P>0.05).

2.4 Effects of Dietary Nutrient Level on Flavor

As shown in , dietary nutrient level had no significant effects on color/shape, aroma, flavor, tenderness, juiciness, or breast muscle size of either male or female broilers (P>0.05).

2.5 Effects of Dietary Nutrient Level on Plasma Biochemical Indices

As shown in , dietary nutrient level showed no significant effects on plasma calcium, uric acid, or urea nitrogen contents in either male or female broilers (P>0.05).

3.1 Effects of Dietary Nutrient Level on Growth Performance

Broiler growth and development are closely related to dietary nutrient levels. In this study, during days 1-28 and 29-56, the low nutrient group exhibited lower ADG and ADFI with higher F/G. Liu [20] reported no significant effects of different nutrient levels on growth performance of Jilin Luhua chickens. Li [21] found that low nutrient diets significantly reduced growth performance of Arbor Acres broilers, consistent with Fanatico et al. [22]. Our results demonstrate that high nutrient diets improved ADG and ADFI while reducing F/G in medium-growing Lingnan yellow-feathered broilers, similar to findings by Wang et al. [23] in fast-growing Lingnan birds. Xie et al. [24] reported that high nutrient diets significantly reduced F/G and increased ADG. However, Ma et al. [25] found no significant effects of high nutrient diets on ADG, ADFI, or F/G in Beijing You chickens, and Zhang et al. [26] observed no significant effects of different energy and protein levels on ADG in Silkie chickens. These discrepancies indicate that different breeds respond differently to nutrient levels.

For feed enterprises and farmers, although ADG is an important indicator, feed cost must also be considered to maximize economic returns. Based on comprehensive evaluation of growth performance and weight gain cost, the medium nutrient level is optimal for both sexes during days 1-56.

3.2 Effects of Dietary Nutrient Level on Carcass Quality

Carcass and eviscerated rates are primary indicators of meat production performance, with rates above 80% and 60%, respectively, considered excellent [27]. Our results indicate good meat production performance across all groups. Lin et al. [28] reported that high nutrient diets increased half-eviscerated and breast muscle weights. Yang et al. [29] found that increased energy levels improved slaughter performance in Shiqiza chickens. However, Shen et al. [30] and Zhao et al. [31] reported no significant effects of different energy and protein levels on carcass or eviscerated rates in yellow-feathered broilers, possibly because modest nutrient level variations (within 10%) do not significantly affect carcass quality.

Zhou et al. [32] identified abdominal fat as an important factor affecting carcass quality, with abdominal fat rate increasing linearly with metabolizable energy level within a certain range. High-energy diets can cause excessive fat deposition, and combined high protein and energy levels significantly increase both protein and fat content [32-33]. Due to hormonal differences, females deposit significantly more fat than males [34]. Our results show that high nutrient levels significantly increased abdominal fat rate in females but not males, consistent with previous findings [34]. While abdominal fat accumulation causes losses for producers, consumers, and processors, yellow-feathered broilers require some fat deposition for optimal taste and meat quality [35-36]. From a fat deposition perspective, medium and low nutrient level groups better meet consumer demand for low-fat, high-quality chicken.

3.3 Effects of Dietary Nutrient Level on Meat Quality and Flavor

Appropriate dietary nutrient levels can improve meat quality. Tang et al. [37] reported that high nutrient levels significantly reduced drip loss and increased pH. Increased dietary nutrient levels decreased moisture content in leg and breast muscles [37-38]. Fang et al. [39] found that increased dietary metabolizable energy significantly increased breast muscle pH. Meat color is a primary indicator of appearance and water-holding capacity, with lower L* values indicating darker color, higher a* values indicating greater redness, and higher b* values indicating greater yellowness. L* values exceeding 60 indicate pale, soft, exudative meat with poor water-holding capacity [40]. Our results show good meat quality across all groups, with nutrient level significantly affecting only the 45-min b* value in males, where high nutrient levels increased yellowness. No significant effects were observed on female meat quality, indicating that modest nutrient level variations (10%) have limited impact on meat quality of medium-growing Lingnan yellow-feathered broilers.

Sensory meat quality attributes include aroma, flavor, juiciness, and tenderness. Higher scores indicate better flavor. Our results showed no significant differences in flavor among groups. Li et al. [41] reported significant differences in intramuscular fat content among breeds, which correlated significantly with muscle flavor. Arkfield et al. [42] found that feeding pigs different energy levels affected loin sensory characteristics, with low-level feeding reducing juiciness compared to high-level feeding. These findings suggest that meat flavor in broilers is more closely related to breed, feed additives, and feeding methods than to nutrient level.

3.5 Effects of Dietary Nutrient Level on Plasma Biochemical Indices

Wei et al. [43] suggested that plasma biochemical indices reflect nutrient metabolism. Plasma calcium and phosphorus levels can indicate nutritional status, though homeostatic mechanisms maintain relatively stable plasma calcium across a wide range of dietary calcium levels. Our results are consistent with this, showing no effect of dietary nutrient level on plasma calcium. Plasma uric acid and urea nitrogen are important indicators of protein metabolism and nutritional status; excessively high or low protein levels are detrimental to nitrogen deposition and protein utilization [44]. Liu [45] found no significant effects of different protein levels on plasma urea in Guangxi yellow chickens. Feng et al. [46] also reported no significant effects of different energy and protein levels on plasma uric acid, total protein, or albumin. Our results align with these findings, indicating that modest adjustments in dietary nutrient level do not significantly affect protein metabolism or calcium deposition.

4 Conclusion

Based on comprehensive evaluation of growth performance, weight gain cost, carcass quality, meat quality, and plasma biochemical indices, we recommend medium nutrient level diets for both male and female medium-growing yellow-feathered broilers during days 1-28 and 29-56, and high nutrient level diets during days 57-84 under the conditions of this experiment.

References

[1] 李莉, 卜泽明, 罗世乾, 等. 日粮能量和蛋白水平对桂香雏鸡饲料营养物质表观消化率的影响 [J]. 南方农业学报,2015,46(2):344-348.

[2] MIAH M Y,CHOWDHURY S D,BHUIYAN A K F H.Effect of different dietary levels of energy on the growth performance and meat yield of indigenous chicken reared in confinement under rural condition bangladesh[J].International Journal Animal Resources,2016,1(1):53-60.

[3] 孙作为. 饲养密度和饲粮营养影响肉鸡生长、胴体组成及腿部健康的研究 [D]. 博士学位论文. 北京: 中国农业大学,2013.

[4] SIKUR V R,ROBINSON F E,KORVER D R,et al.Effects of nutrient density on growth and carcass traits in fast-and slow-feathering female turkeys[J].Poultry Science,2004,83(9):1507-1513.

[5] 周桂莲, 蒋宗勇, 林映才, 等.22~42 日龄黄羽肉鸡饲粮粗蛋白质需要量的研究 [C]//中国畜牧兽医学会动物营养学分会学术研讨会论文集. 北京：中国畜牧兽医学会动物营养学分会，2004.

[6] 洪平, 蒋守群, 周桂莲, 等.43～63 日龄黄羽肉鸡钙需要量研究 [J]. 优质鸡的改良生产暨发展研讨会论文集.[S.l.]:[s.n.],2011.

[7] 蒋宗勇, 周桂莲, 李得忠, 等. 不同非植酸磷和基因工程酵母菌植酸酶水平对 43-63 日龄黄羽肉鸡生长和胫骨发育的影响 [C]//全球肉鸡产业论坛暨第二届中国白羽肉鸡产业发展大会会刊. 北京: 中国畜牧业协会禽业分会,2010.

[8] 蒋宗勇, 刘小雁, 蒋守群, 等.43-63 日龄黄羽肉鸡锌需要量的研究 [J]. 中国农业科学,2010,43(20):4295-4302.

[9] 于欢, 蒋守群, 刘梅, 等.1～21 日龄黄羽肉鸡钠、氯的需要量 [J]. 动物营养学报,2017,29(3):786-797.

[10] 周桂莲, 林映才, 蒋宗勇, 等.1~21 日龄黄羽肉鸡饲料赖氨酸需要量的研究 [C]//动物营养与饲料研究——第五届全国饲料营养学术研讨会论文集. 珠海: 中国畜牧兽医学会动物营养学分会,2006.

[11] 席鹏彬, 林映才, 蒋守群, 等.43~63 日龄黄羽肉鸡可消化蛋氨酸需要量的研究 [C]//第六次全国饲料营养学术研讨会论文集. 杨凌: 中国畜牧兽医学会动物营养学分会,2010.

[12] 席鹏彬, 林映才, 蒋宗勇, 等. 饲粮苏氨酸水平对 0~21 日龄黄羽肉鸡生长性能、胴体品质和免疫功能的影响 [C]//中国畜牧兽医学会动物营养学分会第十次学术研讨会论文集. 杭州: 中国畜牧兽医学会动物营养学分会,2008.

[13] 席鹏彬, 林映才, 蒋宗勇, 等. 饲粮色氨酸水平对 0~21 日龄黄羽肉鸡生长性能、胴体品质和体成分沉积的影响 [C]//中国畜牧兽医学会 2008 年学术年会暨第六届全国畜牧兽医青年科技工作者学术研讨会论文集. 广州: 中国畜牧兽医学会,2008.

[14] 郑春田, 林映才, 蒋宗勇, 等.43~63 日龄黄羽肉鸡异亮氨酸需要量研究 [C]//中国畜牧兽医学会动物营养学分会第十次学术研讨会论文集. 杭州: 中国畜牧兽医学会动物营养学分会,2008.

[15] GAO J,LIN H, WANG X J,et al.Vitamin E supplementation alleviates the oxidative stress induced by dexamethasone treatment and improves meat quality in broiler chickens[J].Poultry Science,2010,89(2):318-327.

[16] 杨宽民, 蒋宗勇, 周桂莲, 等. 黄羽肉鸡维生素 D3 需要量研究 [C]//第六次全国饲料营养学术研讨会论文集. 杨凌: 中国畜牧兽医学会动物营养学分会,2010.

[17] 阮栋, 蒋守群, 周桂莲, 等. 饲粮维生素 B2 水平对 22～42 和 43～63 日龄黄羽肉鸡生长性能、免疫功能、血清抗氧化指标、肝脏酶活和胴体品质的影响 [C]//第六次全国饲料营养学术研讨会论文集. 北京：中国畜牧兽医学会动物营养学分会，2010.

[18] 洪平. 黄羽肉鸡维生素 A 需要量的研究 [D]. 硕士学位论文. 广州: 华南农业大学,2010.

[19] JIANG S,JIANG Z,LIN Y,et al.Effects of different rearing and feeding methods on meat quality and antioxidative properties in Chinese Yellow male broilers[J].British Poultry Science,2011,52(3):352-358.

[20] 刘琳. 不同营养水平对吉林芦花鸡生长性能和呼吸熵的影响 [D]. 硕士学位论文. 长春: 吉林农业大学,2017.

[21] 李文斌. 不同光照制度和营养水平对肉仔鸡生产性能、肉品质及免疫功能的影响 [D]. 硕士学位论文. 兰州: 甘肃农业大学,2010.

[22] FANATICO A C,PILLAI P B,EMMERT J L,et al.Meat quality of slow-and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or with outdoor access[J].Poultry Science,2007,86(10):2245-2255.

[23] 王薇薇, 蒋守群, 周桂莲, 等. 不同饲粮营养水平对岭南黄羽肉鸡生产性能和肉品质的影响 [C]//第六次全国饲料营养学术研讨会论文集. 杨凌: 中国畜牧兽医学会,2010:24.

[24] 谢淑芳, 刘秀云. 饲粮不同能量水平对肉仔鸡生产性能的影响 [J]. 黑河科技,2003(1):11-12.

[25] 马淑梅, 华登科, 郭艳丽, 等. 饲粮营养水平对黄羽肉鸡生长性能、肉品质和性成熟的影响 [J]. 动物营养学报,2016,28(1):217-223.

[26] 张学余, 韩威, 苏一军, 等. 饲料能量和蛋白含量对苏禽乌骨鸡日增重的影响 [J]. 江西农业大学学报,2010,32(2):199-205.

[27] 王福明. 普格土鸡屠宰性能及肌肉品质的测定 [J]. 畜禽业,2006(10):33-34.

[28] 蔺淑琴, 李金录, 史兆国, 等. 日粮不同营养水平对黄羽肉鸡屠宰性能及肉品质的影响 [J]. 中国畜牧兽医,2008,35(8):9-13.

[29] 杨耐德, 尹福泉, 黄晓亮, 等. 日粮不同营养水平对石岐杂肉鸡屠宰性能及肌肉品质的影响 [J]. 贵州农业科学,2010,38(7):151-154.

[30] 申春平, 吴兆林, 章明, 等. 不同日粮、不同品种黄鸡增重及屠宰性能的研究 [J]. 中国禽业导刊,2004,21(5):40.

[31] 赵衍铜, 张丽萍, 马倩, 等. 日粮不同营养水平对芦花鸡生长性能及屠宰性能的影响 [J]. 饲料工业,2012,33(17):25-27.

[32] 周桂莲, 林映才, 蒋守群, 等. 饲粮代谢能水平对 22~42 日龄黄羽肉鸡生长性能、胴体品质以及部分血液生化指标影响的研究 [J]. 饲料工业,2004,25(3):35-38.

[33] JACKSON S,SUMMERS J D,LEESON S.Effect of dietary protein and energy on broiler carcass composition efficiency nutrient utilization[J].Poultry Science,1982,61(11):2224-2231.

[34] 陈继兰, 赵桂苹, 郑麦青, 等. 快速与慢速肉鸡脂肪生长与肌苷酸含量比较 [J]. 中国家禽,2002,24(8):16-18.

[35] 刘定发, 林勇, 蒋隽, 等. 性别对优质黄羽肉鸡屠体性状和肌肉品质的影响 [J]. 中国畜牧兽医,2005,32(11):23-25.

[36] 缪宪纲, 温汝波, 邱立云. 优质三黄鸡饲养技术 [M]. 广州: 广东科技出版社,1990.

[37] TANG M Y,MA Q G,CHEN X D,et al.Effects of dietary metabolizable energy and lysine on carcass characteristics and meat quality in Arbor Acres broilers[J].Asian-Australasian Journal of Animal Science,2007,20(12):1865-1873.

[38] PESTI G M,BAKALLI R I,CERVANTES H M,et al.Studies on semduramicin and nutritional responses:2.methionine levels[J].Poultry Science,1999,78(8):1170-1176.

[39] 方立超, 宋代军, 阚宁, 等. 饲粮能量和蛋白质水平对肉鸡肉质的影响 [J]. 西南农业学报,2002,15(3):98-104.

[40] 孙厚法. 山东省四个地方鸡种产肉性能和肉品质的比较研究 [D]. 硕士学位论文. 泰安: 山东农业大学,2015.

[41] 李龙, 蒋守群, 郑春田, 等. 不同品种黄羽肉鸡肉品质比较研究 [J]. 中国家禽,2015,37(21):6-10.

[42] ARKFIELD E K,HAMMAN E,BERGER J E,et al.Sensory characteristics of loins from pigs divergently selected for residual feed intake and fed diets differing in energy[R].[S.l.]:Iowa State University,2014:56.

[43] 韦志坚, 张朝胜, 何宝祥, 等. 广西奶水牛产后主要脂类指标的动态监测 [J]. 广西畜牧兽医,2010,26(1):42-43.

[44] 代腊, 董信阳, 袁超, 等. 日粮中添加缬氨酸对蛋鸡蛋白质代谢、抗氧化及免疫功能的影响 [C]//中国畜牧兽医学会动物营养学分会第十一次全国动物营养学术研讨会论文集. 长沙: 中国畜牧兽医学会动物营养学分会,2012.

[45] 刘璐. 广西东兰乌鸡生长期适宜能量和蛋白质水平的研究 [D]. 硕士学位论文. 南宁: 广西大学,2016.

[46] 巧凯玲, 蒋启东, 董泽敏, 等. 夏季不同能量和蛋白水平对 30~60 日龄麻鸭物质代谢率、血清生化指标和肌肉成分的影响 [J]. 中国家禽,2014,36(5):24-30.

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