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RESEARCH ARTICLE

Effects of Rearing Systems and Dietary Regimens on Growth Performance, Carcass Yield, and Meat Quality of Japanese Quails (*Coturnix coturnix japonica*)

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ABSTRACT

This experiment compared the impacts of cage and deep-litter rearing systems and three dietary plans (standard diet, energy-rich diet, and protein-optimized diet) on the growth performance, carcass yield, and meat quality of Japanese quails (*Coturnix coturnix japonica*). There were 720 one-day old quail chickens that were assigned to a 2x3 factorial with six treatment groups and four replicates per treatment (30 birds per replicate). The reared birds were 42 days old; growth parameters (body weight, feed intake, feed conversion ratio), carcass characteristics (dressing percentage, breast and thigh yield, abdominal fat), and meat quality parameters (pH values, color, water holding ability, tenderness, proximate composition, and sensory characteristics) were taken. The feeding system influenced the intake of feed and other parameters of activity substantially, whereas the diet plan had a great impact on the growth rate, carcass composition and meat proximal composition. Caged bird reared better than deep-litter in terms of body weight gain and feed conversion ratio, whereas deep-litter birds were more energetic and lean. The high-energy diet enhanced fat deposition and intramuscular fat leading to slightly reduced water-holding capacity and the sensory perception. The protein-optimized diet generated better yield in the breast muscle and low serum urea nitrogen (indicator of better protein utilization). There were major interplays between rearing system and diet in breast yield and meat tenderness. Comprehensively, the findings indicate that the rearing environment should be considered when formulating the diet in Japanese quail production to enhance the effectiveness of production and meat quality; the balance between the amount of energy and protein intake and housing must be optimized by the producer.

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1. Introduction

The Japanese quail (*Coturnix coturnix japonica*) is a popular commercial poultry production bird because it has a short gestation period, grows fast, produces high eggs, and has a good feed conversion ratio [1]. Quail meat is currently becoming popular due to its positive nutrition and cooking values. Manufacturers always want management and nutrition programs that improve the performance of growth, carcass yield and meat quality without increasing the cost of production [2].

There are two macro factors that have a high impact on the productive performance and quality of quail meat: the rearing regime and diet structure. Conventional cages, aviaries and deep-litter (floor) rearing systems vary in terms of stocking density, movement freedom, microclimate and expression [3]. These variations may affect energy use, levels of stress, and, therefore, growth and carcass composition. Energy intake and specific amino acid (EAA) ratio are used to stimulate the effectiveness of nutrient oxidation, muscle gain, and fat storage. The interaction between housing and diet is more than simply high-activity caged birds developing excess fat when fed a diet optimized at low activity, or low-activity caged birds developing excessively toward maintenance and growth requirements when fed an enriched diet: nutrient requirements differ depending on the activity levels of the bird [4].

The relationship between the rearing systems and the dietary regimes needs to be well understood to be able to customize feeding programs that enhance the growth and quality of the meat obtained at the least wastes and the smallest environmental impact. Various researches in poultry species demonstrate an interaction effect between housing and nutrition on feed consumption, carcass composition, and meat sensory properties, but there is scanty evidence of such an effect in Japanese quail between a variety of diets and housing conditions [1,2].

The research question addressed in this study was to investigate in a systematic manner, the effects of two prevalent rearing systems (cage and deep-litter) and three dietary regimens (standard, energy-rich, and protein-optimized) on the growth performance, carcass yield, and meat quality of Japanese quails at the end of a normal commercial rearing period. Our hypotheses were that (1) caged production would result in an increased weight gain and feed ratio since the animals would be less active; (2) the high-energy diet would result in increased fat deposition and intramuscular fat, which would then lead to poorer meat quality traits; and (3) the protein-balanced diet would result in an improved lean yield and a decreased amount of nitrogen wastage. Relationships between rearing system and diet were studied to give viable recommendations to producers.

2. Materials and Methods

2.1. Experimental design and birds

One-day old mixed-sex Japanese quail chicks (initial mean weight 7.6 + 0.4 g) were obtained (n= 720) in a commercial hatchery. There was random assignment of birds into a 2x3 factorial design with two rearing systems (cage and deep-litter) and three diet plans (standard diet -CR, energy-rich diet -ER, protein-optimized diet -PR). The treatment groups were repeated four times (n = 30) and the number of birds in each group was 6 (n = 120 birds in the treatment group). The experiment lasted 42 days.

2.2. Housing and management

2.2.1 Cage system

Birds kept in cages were caged in battery-like cages (3 tiers) with 30 birds in each cage (dimensions set to match welfare requirements), having ad lib access to food and water in troughs and nipple drinkers respectively. The temperature was set to 37-38 Cº during the first week and then gradually reduced to 22-24 Cº in week six. The first week was under a 23L:1D regime, after which it was under 20L:4D.

2.2.2 Deep-litter system

Deep-litter birds were kept in pens lined with wood shavings (5 cm depth) and the floor area per bird was similar to cages in order to maintain stocking density. There was ad libitum access to feeders and drinkers. The litter was also observed and changed where needed to reduce ammonia and caking. Cage housing was comparable to environmental control parameters (temperature, ventilation).

2.2.3 Dietary regimens

To satisfy or surpass nutrient needs of growing quail, diets were created. Each diet was iso-caloric or altered according to the following: Composition of feed (approximately): Standard diet (SR): prepared to the normal industry specifications (metabolizable energy [ME] of ~2900 kcal/kg, crude protein [CP] of ~24], recommended EAA profile). Energy-rich diet (ER): higher ME (~3100 kcal/kg) through greater intake of vegetable oil and cereal to isolate the energy effect on CP (kept at 24%).

Protein-optimized diet (PR): CP rose to 27% alongside an optimized essential amino acid ratio (supplemented synthetic lysine and methionine) with ME being equivalent to SR (approximately 2900 kcal/kg). Each of the diets consisted of vitamins and mineral premixes to satisfy the micronutrient requirements. Two-stage growth (1-14 d) The diets were compared using a starter (1-14 d) and grower (15-42 d) feed phase with the proportional changes kept constant. Proximate composition was tested on feed samples by the standard AOAC procedures to verify formulated figures [5].

2.3 Growth performance

Replicate body weight (BW) and feed intake (FI) were measured at days 42. Based on them, average daily gain (ADG), average daily feed intake (ADFI), and feed to gain ratio (FCR; feed/gain) in starter, grower, and general stages were determined. Deaths were counted on a daily basis and cumulative number of deaths was used to correct the performance calculations.

2.4 Blood biochemical parameters

On day 42, there was random selection of four birds per replicate (16 per treatment) and their fasting at 6 h prior to blood sampling through jugular venipuncture. Separated serum was frozen at -20Cº until examination. The blood biochemistry was measured as: glucose, total protein, albumin, globulin (calculated), urea nitrogen (UN), triglycerides, total cholesterol, aspartate aminotransferase (AST), and creatinine. Normal automated clinical chemistry measures were utilized.

2.5 Slaughter and carcass evaluation

After blood sampling, the same birds were slaughtered humanly as per the normal procedures. Carcases were defeathered, eviscerated, and chilled (4 Cº, 24 h). Percentage of dress (hot and chilled), weight of breast muscle, weight of thigh, weight of abdominal fat pad as well as weight of internal organs (liver, heart, gizzard) were noted and were expressed as a percentage of live body weight.

2.6 Meat quality analyses

The samples of the breast muscles (pectoralis major) were used to measure the quality of meat. Measurements included: pH: pH45 and pH24 at 45 min and 24 h after the experiment, respectively, with a calibrated pH meter. Colour: CIE L (lightness), a (redness), and b (yellowness) on the cut surface, 30 min bloom monitored on the cut surface on a colourimeter. Water holding capacity (WHC): drip loss (48 h) and cooking loss is measured. Shear force (tenderness): This was assessed by the Warner-Bratzler shear force on cooked samples. Proximate composition: moisture, protein, fat, and ash done by AOAC techniques. Sensory evaluation: a trained panel (n=8) was used to evaluate the appearance, juiciness, tenderness, flavor and overall acceptability of cooked breast samples using a hedonic scale of 9 points.

2.7 Statistical analysis

The two-way ANOVA was employed with rearing system and diet as the fixed factors and their interaction being the third variable. Experimental unit of growth performance and carcass characteristics was replicate, whereas, individual bird was the experimental unit of blood and meat quality measures. Tukey HSD was used to do post hoc comparisons. The level of significance was set at P = 0.05. The data is given as means + standard error (SE).

3. Results

Body weight gain, feed intake, and feed conversion ratio are summarized in Figure 1 and 2. Final BW and ADG were also much higher (P < 0.001) in cage-reared birds as compared to litter-reared birds. The protein-optimized diet (PR) gave the final BW and the optimal FCR in cages (P < 0.01). Par also enhanced better FCR than SR and ER in the two types of housing (P < 0.05). ER promoted final BW compared to SR in both systems, and was linked with higher feed intake and marginally low FCR compared to PR. There was low mortality in all the treatments (less than 3.5) and not any significant difference in mortality among groups (P > 0.05).

Figure 2: Average daily weight gain, feed conversion ratio and Mortality.

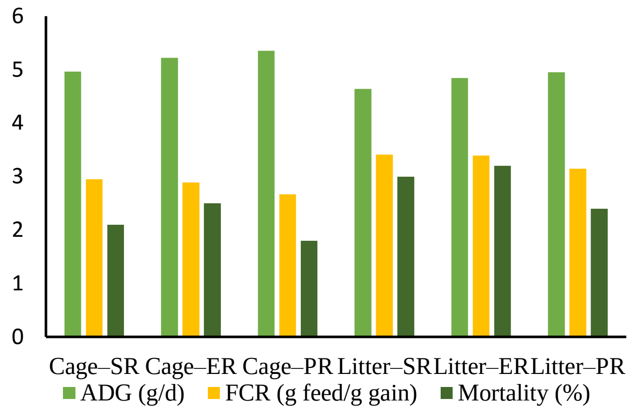
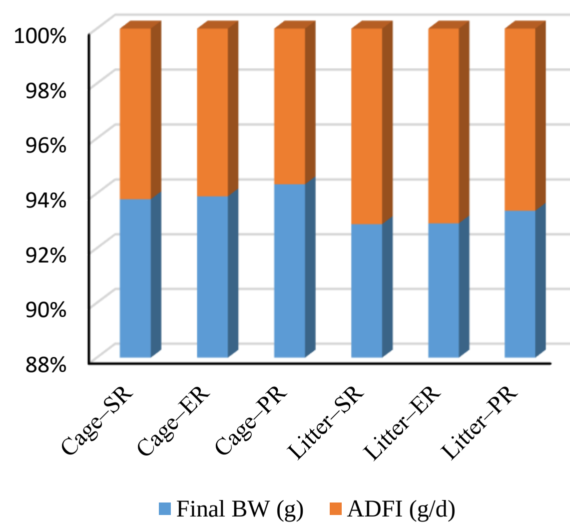


Figure 2: Final body weight gain and Average daily feed intake.



Serum biochemical indices of quails (day 42) under different rearing and diet summarized in Table 1 and Figure 3. Protein-optimized diet had better total serum protein and lower UN, which are indicators of better protein use (P < 0.05). ER increased serum triglycerides and cholesterol (P < 0.05) indicative of increased lipid deposition. Small increases in AST in ER groups suggested mild hepatic stress or metabolic acclimatization to an increased dietary fat although values were within physiological limits of quail.

Carcass characteristics (chilled carcass) of quails at 42d characterized in Table 2. Cage birds were found to have better dressing percentage and breast yield than litter birds (P < 0.01). PR enhanced the yield of the breast significantly (P < 0.01) in both systems. ER The outcome of ER in the two systems was increased abdominal fat in the higher abdominal area (P < 0.001), which is in line with elevated serum lipids.

Table 1. Serum biochemical indices of quails (day 42) under different rearing and diet treatments (means ± SE, n = 16 birds/treatment).

Parameter	Cage–SR	Cage–ER	Cage–PR	Litter–SR	Litter–ER	Litter–PR
Glucose (mmol/L)	10.2 ± 0.2	10.6 ± 0.2	11.1 ± 0.4	9.8 ± 0.2	10.1 ± 0.2	10.4 ± 0.3
UN (mmol/L)	4.1 ± 0.2	4.3 ± 0.2	3.6 ± 0.2*	4.4 ± 0.2	4.6 ± 0.2	3.9 ± 0.2*
Triglycerides (mmol/L)	0.85 ± 0.05	1.12 ± 0.06*	0.88 ± 0.04	0.77 ± 0.05	0.99 ± 0.05*	0.82 ± 0.04
Cholesterol (mmol/L)	3.2 ± 0.1	3.7 ± 0.1*	3.3 ± 0.1	3.0 ± 0.1	3.4 ± 0.1*	3.1 ± 0.1

Table 2. Carcass characteristics (chilled carcass) of quails at 42 d (means ± SE, n = 16).

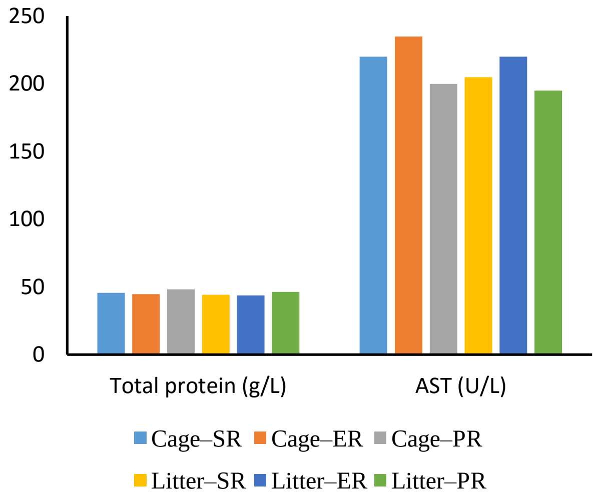
Parameter	Cage–SR	Cage–ERR	Cage–PR	Litter–SR	Litter–ER	Litter–PR
Dressing % (chilled)	65.2 ± 0.2	66.4 ± 0.1	69.1 ± 0.2*	62.8 ± 0.3	64.9 ± 0.4	66.5 ± 0.4
Breast yield (%LW)	21.4 ± 0.5	20.8 ± 0.5	22.0 ± 0.6*	19.6 ± 0.1	19.2 ± 0.6	20.1 ± 0.5*
Abdominal fat (%LW)	0.67 ± 0.0	1.10 ± 0.0*	0.71 ± 0.0	0.51 ± 0.0	0.85 ± 0.0*	0.60 ± 0.0
Thigh yield (%LW)	10.2 ± 0.3	10.5 ± 0.3	10.8 ± 0.3	10.0 ± 0.3	10.3 ± 0.1	10.5 ± 0.1

Meat quality characteristics of breast muscle (means ± SE, n = 16) characterized in Table 3. ER decreased pH24 and L* (lighter color), drip and cooking losses, and shear force (less tender), and enhanced intramuscular fat (P < 0.05). PR raised the content of proteins and enhanced WHC and tenderness (reduced shear force) in comparison to SR and ER (P < 0.05). Sensory panel PR meat was preferred based on juiciness, tenderness and general acceptability therefore, ER samples scored lower on the basis of their perceived greasier mouthfeel and lowered juiciness.

4. Discussion

The current factorial experiment assessed the effect of rearing environment and dietary formulation of energy/protein as an independent and interactive factor to determine the effect of these factors on the growth, carcass trait and meat quality of Japanese quails. The hypotheses that (1) caged birds have better BW and FCR, (2) greater dietary energy increases lipid deposition and changes meat quality, and (3) protein optimization increases lean yield and protein utilization efficiency are supported [6,3].

Figure 3. Serum biochemical total protein and aspartate aminotransferase



The caged quails in this experiment had better end body weights and increased conversion of feed as compared to deep-litter birds. This is in agreement with the idea that less locomotion in cages will reduce the maintenance energy demands giving the opportunity to more energy partitioning towards growth [6,7]. Litter reared birds generally require more energy to move and require more feed per pound but less net growth, which we found (had higher ADFI and lower ADG and worse FCR) [1,7].

Nonetheless, more litter systems resulted in leaner carcasses (lower abdominal fat) and a minor increase in the homogeneity of meat colour; the welfare issues - including expression of innate behaviours - tend to support litter systems. Producers have to balance between the economy and the target of animal welfare and the quality of products [7]. Cage systems in combination with selective diet can be a better choice in order to achieve certain production objectives (maximizing breast yield in processors); litter systems can become profitable in the case of niche markets that favor animal welfare or lean meat [3,4].

Table 3. Meat quality characteristics of breast muscle (means ± SE, n = 16).

Parameter	Cage–SR	Cage–ER	Cage–PR	Litter–SR	Litter–ER	Litter–PR
pH24	5.91 ± 0.0	5.81 ± 0.0*	5.82 ± 0.0*	5.85 ± 0.0	5.77 ± 0.0	5.88 ± 0.0*
Drip loss (%)	2.6 ± 0.2	3.0 ± 0.3*	2.3 ± 0.2*	2.1 ± 0.2	3.3 ± 0.1*	2.0± 0.1*
pH45	6.47 ± 0.0	6.45 ± 0.0	6.49 ± 0.0	6.50 ± 0.0	6.49 ± 0.0	6.54 ± 0.0
L* (lightness)	52.1 ± 0.8	54.3 ± 1.0*	50.6 ± 0.7*	50.8 ± 0.9	53.0 ± 1.0*	49.7 ± 0.8*
Cooking loss (%)	18.5 ± 0.7	20.6 ± 0.8*	17.0 ± 0.6*	17.2 ± 0.7	19.5 ± 0.8*	16.5 ± 0.6*
Shear force (N)	28.5 ± 1.1	31.2 ± 1.2*	25.8 ± 1.0*	26.3 ± 1.0	29.4 ± 1.1*	24.9 ± 1.0*
Overall sensory score (1–9)	7.2 ± 0.2	6.6 ± 0.2*	7.7 ± 0.2*	7.5 ± 0.2	6.9 ± 0.2*	8.0 ± 0.2*
Protein (%)	22.7 ± 0.3	21.8 ± 0.3	24.6 ± 0.3*	24.0 ± 0.3	21.3 ± 0.3	25.1 ± 0.3*
Fat (%)	2.1 ± 0.1	3.6 ± 0.2*	1.8 ± 0.1*	1.5 ± 0.1	2.8 ± 0.2*	1.4 ± 0.1*

Dietary energy (ER) increased final BW but also drastically increased abdominal and intramuscular fat, serum triglycerides and cholesterol and modified meat quality (greater drip and cooking losses, lighter color and reduced tenderness). Increased dietary energy in the absence of similar increases in lean tissue-building nutrients results in increased lipogenesis and fat accretion. In the case of quail meat producers, the fat buildup is frequently not desirable - it decreases the yield of carcass containing sellable lean meat and it is possible that it decreases how well the meat is accepted by consumers [5,7].

ER-related decreases in pH24 and increased L* (lighter color) are similar to the pale, soft, exudative (PSE)-like texture in broiler meat, that is characterized by high levels of rapid postmortem glycolysis leading to low pH and low WHC. Although the effect here was also moderate, the trend indicates that high-energy diets could have an indirect effect on meat quality by impacting muscle glycogen storage or pre-slaughter stress reaction. Care during pre-slaughter management, energy-protein ratio, and dietary measures (e.g. the use of good fats and antioxidants) can reduce adverse consequences [3,4,5].

Protein-optimized diet (PR) continued to enhance the protein and fat content of meat on a basis of its weight, and reduced the BUN (a ratio of less catabolic amino acids) as well as FCR compared with SR and ER. Improvement of dietary CP and regulation of EAA profile (supplemental lysine, methionine) contributes to the efficient muscle protein generation, especially in breast tissue, which is very sensitive to lysine. Reduced BUN in PR birds indicates that the birds have better retention of nitrogen and less excretion of nitrogen to the environment, an important aspect of sustainability [5].

Further, PR enhanced meat tenderness and WHC, probably because of increased deposition of muscle protein and differentiation of intramuscular connective tissue structure. These results underline the economic and environmental benefits of the development of diets to match the EAA requirements correctly instead of increasing crude protein in a random manner [5]. Major interactions draw to the conclusion that the housing system defines the best strategy of diet. Indicatively, the positive influence of PR on the breast yield was greater in caged birds- maybe due to the low activity of dietary amino acids into muscle but not into maintenance or activity. On the other hand, the toughness related to ER was higher in litter-reared birds which could be due to a combination of higher activity, changes in muscle fibre structure and lipid penetration [8].

This is practically to imply that manufacturers should not use a single diet on diverse rearing systems. Rather, nutritionists ought to bear in mind the rearing environment in determining the target energy and the amino acid densities [9]. A moderate-energy protein-optimized diet could be the most appropriate diet to achieve optimal cage production using the approach of maximizing both the breast yield and the FCR. In litter systems that are more energetic and whose carcass leanness is important, diets that are slightly reduced in energy and whose protein content is sufficient to repair and maintain may be superior [6,7].

The quality of meat between the two was insignificant but consistent: PR increased sensory scores whereas ER lowered overall acceptability. The intramuscular fat may make the meat tastier, but too much results in a slick feel of the mouth, which is not appreciated by the panelists. ER samples have a greater loss on drip and cooking, which lowers yield and juiciness which is crucial in economics. Manufacturers who are appealing to higher markets ought to give focus to diets that maximise tenderness and juiciness (e.g. controlled energy with optimized amino acid makeup), and take into account post-harvest handling methods to maintain WHC [10].

5. Conclusion

Dietary regimen and rearing system have significant effects on the growth performance, carcass yield and meat quality of Japanese quail. The cage housing yielded more body weights and better feed efficiency whereas deep litter rearing resulted in enhanced activity and lean carcasses. Protein-optimized diet enhanced the breast yield, meat protein content, and feed ratio and minimized the nitrogen excretion. On the other hand, a high energy diet stimulated fat accumulation and EA had adverse impacts on the parameters of meat quality (WHC, tenderness, sensory acceptability). Notably, the housing-nutrition interactions show that nutrition programs must be environment specific: optimization of protein is the most effective in cage based systems with the goals of high breast yield, whereas, in litter-based systems, energy management is a crucial factor to prevent unwanted fat deposition. The results can help producers to choose the combinations of housing and nutrition that correspond to the production objectives, the quality targets of products, and sustainability objectives.

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