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Effect of Cage Stocking Density and Dietary Nutrient Density on Productive Performance, Egg Quality and Blood Parameters of Japanese Quail

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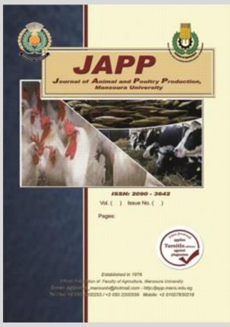

ABSTRACT

This study was undertaken to investigate stocking density (SD) and nutrient density (ND) effects on productive performance, egg quality, carcass characteristics, and blood biochemical parameters of Japanese quails. Two hundred eighty-eight quails were randomly divided to 6 experimental groups (each with 4 replications) and kept at three rates of cage SD (277.8, 208.3 and 166.7 cm^2/bird). Three of these groups were fed on a normal nutrient density diet and the second three groups were fed on a high nutrient density diet (105% of the recommended nutrient requirements for laying quails) and managed similarly from 7 to 19 weeks of age. Carcass characteristics and most blood parameters, certain criteria of productive performance of quails were not affected by SD and ND. Increasing SD impaired EPR, DFI, and DEM of quails. However, increasing ND improved EPR, DFI and DEM but had no effect on all criteria of egg quality. Most egg quality traits were not affected by SD, while YI was deteriorated and ST improved with increasing SD. There were inconsistent differences in serum levels of MDA and COR, but P level increased due to increasing SD. As ND increased serum LDL-C concentration of quails increased while level of uric acid decreased. The SD by ND interactions insignificantly affected all estimated criteria of quail hens. Conclusively, an optimal SD for laying quails is suggested to be 277.8 cm^2/hen for normal productive performance, egg quality and blood parameters. Increasing ND can alleviate the negative effects of high SD on laying performance of quails.

Keywords: Egg, Carcass, Blood, Japanese quails.

INTRODUCTION

Japanese quail (*Coturnix japonica*) is an important poultry species that are raised in most countries of the world for meat and egg production. Poultry producers prefer to keep the laying quails in battery cages rather than in floor pens. A good Japanese quail hen can produce up to 300 eggs yearly. Stocking density (SD) is defined as the number of birds (or kilograms of live body weight) reared in a square meter of a cage or floor pen. It is also defined as the number of square centimeters required per bird in a cage or floor pen. Increasing SD for laying quails as a managerial strategy to lessen the production cost is acceptable. But too high SD (overcrowding) of laying quails can adversely affect their welfare, health, performance and profitability. However, an ideal SD for laying quails maintains their proper requirements for ventilation, physical activity, and access to feed and water; thus, they can achieve optimal productive performance. In this regard, Faitarone *et al.* (2005) evaluated the performance of Italian quails caged at four levels of SD (264, 211, 176 and 151 cm^2 per bird) and observed a linear reduction in egg weight, feed intake, egg production rate, egg mass and feed conversion per dozen eggs with increasing the SD. El-Tarabany *et al.* (2015) reported that increasing the SD for Japanese quails from 200 to 143 cm^2 per bird depressed their exterior and interior parameters of egg quality. However, Bourdon *et al.* (2021) observed that productive performance and eggshell quality traits of laying quails were not affected by different stocking densities in cages (112.2, 102.0, 93.5 and 86.3 cm^2/bird).

Interestingly, the perusal of the scientific literature reveals that the ideal SD for laying Japanese quails is inconclusive. As per El-Shafei *et al.* (2012) suggested that ideal SD for laying quail is 233 cm^2/bird to achieve optimal performance and viability and minimize the physiological stress due to high cage SD. While El-Tarabany (2016) reported that when cage SD of laying Japanese quails was lower than 200 cm^2/bird there were significant depressions in egg fertility, hatchability, egg production criteria and some immunity and welfare parameters. In a later study, Ratriyanto *et al.* (2020) recommended that the best SD for Japanese quails is 45 birds per m^2 (222.2 cm^2/bird), combined with ascorbic acid supplementation (250 mg/kg), when reared in a hot climate. Recently, Bourdon *et al.* (2021) evaluated the effects of four SD for laying Japanese quails and found that different SD did not affect performance and eggshell quality of laying quails, and suggested that the best SD is 102 cm^2/quail. Also, Aro *et al.* (2021) evaluated the effects of four stocking densities on the performance and egg quality of Japanese quails and stated that Japanese quails kept at 173.43 or 132.10 cm^2/bird performed well as did those kept at the standard SD (252.20 cm2/quail bird) and hence could still be adopted in quail farming without compromising their welfare and performance. More recently El Sabry *et al.* (2022) stated that taking the economics-welfare balance into account the optimal range of SD for laying quails is 200-230 cm^2/bird. Several managerial and nutritional strategies can be adopted to minimize the negative effects of high SD on the welfare and performance of poultry. Some of these strategies have been reported including dietary supplementation with vitamin E (Selvam *et al.*, 2017), yeast extract (Reda *et al.*, 2021), organic acids (Dai *et al.*, 2022), probiotics, prebiotics, synbiotics, plant-derived products, vitamins, and fatty acids (Sugiharto, 2022) and increasing the ND of the diet (DePersio *et al.*, 2015; Khatibi *et al.*, 2021; Gül *et al.*, 2022). Therefore, the

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present study was designed to evaluate the response of laying Japanese quail stocked at three cage densities to feeding high-nutrient-density diets.

MATERIALS AND METHODS

Place and Period of Study:

This study was carried out at the Poultry Research Unit, Agricultural Research and Experimental Station, Faculty of Agriculture, Mansoura University, Egypt; during the period from May to July, 2022.

Birds, Diets and Management:

The present study was performed on 288 7-wk-old Japanese quails (96 ♂ and 192 ♀) for 12 weeks. Birds were kept in naturally ventilated laying house equipped with community cages, each having the following dimensions: 50 cm length, 50 cm width and 25 cm height. Three cage SD (9, 12 and 15 quails per cage: equivalent to 277.8, 208.3 and 166.7 cm^2/bird) were evaluated in this study. Each experimental group of quails included four replications. Each replicate group of quails with a sex ratio of two females: one male was kept in a cage and fed on a normal nutrient density diet (NND: as recommended by NRC, 1994) or high nutrient density diet [(HND: 105% of the recommended nutrient requirements for laying quails: metabolizable energy (ME), crude protein (CP), Ca, P, lysine, methionine and total sulfur amino acids (methionine + cystine)] from 7 to 19 weeks of age. All birds were given their respective feed and fresh water *ad libitum* and exposed to a photoperiod of 16 hours daily and managed similarly. The ingredient and nutrient compositions of the NND and HND diets are presented in Table 1.

Table 1. Feed ingredients and nutrient concentrations of the experimental diets fed to laying Japanese quail from 7 to 19 weeks of age

Ingredients (%)	Nutrient Density level (%)	
	(NND: 100% of NRC)	(HND: 105% of NRC)
Yellow corn, ground	63.01	64.48
Soybean meal (44% CP)	20.00	9.00
Corn gluten meal (60% CP)	8.97	17.79
Limestone, ground	5.80	6.04
Dicalcium phosphate	1.25	1.45
Sodium chloride (NaCl)	0.30	0.30
Vit. & Min. Premix¶	0.30	0.30
L-Lysine.HCl	0.29	0.60
DL-methionine	0.08	0.04
Total	100.00	100.00
Calculated analysis (NRC, 1994):		
Metabolizable energy (kcal/kg)	2903	3045
Crude protein (%)	20.03	21.05
Ether extract (%)	2.77	2.96
Crude fiber (%)	2.90	2.28
Lysine (%)	1.02	1.06
Methionine (%)	0.45	0.47
Methionine plus cystine (%)	0.79	0.85
Calcium (%)	2.53	2.63
Non-phytate phosphorus (%)	0.35	0.37

¶: Each 3 kg premix contains: Vit. A, 12,000,000 IU; Vit. D_3, 2,500,000 IU; Vit. E, 10 g; Vit. K, 2.5 g; Vit. B_2, 5 g; Vit. B_6, 1.5 g; Vit. B_{12}, 10 mg; Biotin, 50 mg; Folic acid, 1.0 g; Nicotinic acid, 30 mg; Pantothenic acid, 10 g; Antioxidant, 10 g; Mn, 60 g; Cu, 10 g; Zn, 55 g; Fe, 35 g; I, 1.0 g; Co, 250 mg and Se, 150 mg. NND: Normal nutrient density diet. HND: High nutrient density diet.

Performance and Egg Quality Parameters:

All birds were individually weighed at the start (7 weeks of age) and at the end of study (19 weeks of age). Productive performance of quails was evaluated on a 4-wk period basis as hen-day egg production rate (HDEPR), egg weight (EW), daily feed intake (DFI), daily egg mass (DEM) and feed conversion ratio (FCR). At 15 weeks of age, an egg quality test was performed to evaluate some exterior and interior parameters of egg quality. Ninety freshly collected eggs were randomly taken for egg quality test. The estimated egg quality parameters were EW, weights of shell, yolk and albumen, egg shape index (ESI), shell thickness (ST), yolk index (YI), yolk color score (YCS), albumen height (AH) and Haugh units (HU). The egg shape index was determined as egg width multiplied by 100 and divided by egg length (Duman *et al.*, 2016). The eggshell thickness was estimated by a special micrometer as an average of two measures at corresponding positions on the equator of the eggshell. The egg yolk index was calculated as yolk height times 100 divided by yolk diameter (Duman *et al.*, 2016). The yolk color score was measured by means of the Roche yolk color fan. The HU was computed by formula of Haugh (1937). The heights of egg yolk and thick albumen were measured by using a tripod micrometer. The yolk diameter was estimated by an electronic slide caliper.

Carcass Traits and Blood Measurements:

At the end of study (19 weeks of age), eight female quails from each treatment, around its average live body weight (LBW), were randomly chosen and sacrificed after feed depriving for 12 hours. After slaughtering and complete bleeding, carcasses were processed. Weights of carcass yield (CY) and total giblets (TGI) were estimated individually. Thus, the relative weights of CY, TGI, total edible parts (DEP) and inedible parts (IEP) were determined. During slaughtering, 8 blood samples were collected from each treatment in non-heparinized test tubes. Serum samples were separated by centrifugation at 3000 rpm for 10 minutes and stored at -20°C until analysis. Serum concentrations of total protein (TP), albumin (Alb), uric acid (UA), triglycerides (Tri), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), total antioxidant capacity (TAC), malondialdehyde (MDA), Ca, P and corticosterone (COR) were determined. The serum globulin (Glo) was calculated by subtracting the serum Alb level from that of TP. The blood serum activity of alkaline phosphatase (ALP), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were also determined. All blood parameters were estimated by commercial kits.

Statistical Analysis and Experimental Design:

A completely randomized design was used in this study with a factorial arrangement of treatments (3×2), three cage SD (277.8, 208.3 166.7 cm^2/bird) and two levels of nutrient density (NND and HND). The data were statistically processed by a two-way analysis of variance of the Statistical Analysis System (SAS Institute, 2006). When the main effects were significant ($P \leq 0.05$), means were identified according to Tukey (1977). The following statistical model was used: $Y_{ij} = \mu + SD_i + ND_j + SDND_{ij} + e_{ij}$. Where: Yij = observed characteristics; μ = overall mean; SDi = effect of stocking density; i = (1, 2 and 3); NDj = effect of nutrient density; j = (1 and 2); SDNDij = interaction effect of stocking density and nutrient density; eij = experimental random error.

RESULTS AND DISCUSSION

Productive Performance of Japanese Quail:

The effects of cage stocking density (SD) and dietary nutrient density (ND) on productive performance of laying Japanese quail from 7 to 19 weeks of age are given in Table 2. Neither cage SD nor dietary ND affected final LBW, EW or FCR of laying Japanese quail during the whole experimental period (7 to 19 weeks of age). But there were significant effects of cage SD ($P<0.01$) and dietary ND ($P\leq0.05$) on HDEPR, DFI and DEM of quail hens. Increasing cage SD from 277.8 to 166.7 cm^2/bird significantly depressed HDEPR, DFI and DEM, regardless of dietary ND. The depression in HDEPR of quail hens kept at high cage SD (208.3 or 166.7 cm^2/bird) compared with those kept at normal cage SD (277.8 cm^2/bird) is mainly attributed to their lower DFI (Table 2). Although FCR of quail hens was not affected by cage SD but quail hens kept at the two higher cage SD (208.3 or 166.7 cm^2/bird) displayed slightly better ($P>0.05$) means of FCR than that of quails kept at normal cage SD (277.8 cm^2/bird). Such improvement in FCR for quail hens kept at high cage SD (208.3 or 166.7 cm^2/bird) might be because the reduction observed in their DEM was less than that observed in their DFI. Apart from cage SD, increasing dietary ND from the recommended level (100%) to 105% improved hen-day EPR ($P<0.05$), DFI ($P<0.01$) and DEM ($P<0.05$) of quail hens. The interactions between cage SD and dietary ND insignificantly affected ($P>0.05$) performance of laying quails from 7 to 19 weeks of age; therefore, their means were not tabulated.

Our results agree with those of Faitarone *et al.* (2005) they found a linear reduction in feed intake, egg production rate and egg mass of Italian quails with increasing the cage SD from 264 to 151 cm^2 per bird but feed conversion per egg mass was not affected. According to El-Shafei *et al.* (2012), the ideal SD for laying quail is suggested to be 233 cm^2/ bird to achieve optimal performance and viability and minimize the physiological stress due to high cage SD. With laying hens, Asghar Saki *et al.* (2012), increasing the cage SD from 2,000 to 500 cm^2 per hen significantly reduced body weight, EW, HDEPR, egg mass and feed intake from 35 to 47 weeks of age. Our results concur also with those of El-Tarabany (2016), who found that quails caged at normal SD (200 cm^2/bird) had superior HDEPR, EW, and egg mass (EM) to those of quails kept at higher SD (167 or 143 cm^2/bird). In a later report, Ratriyanto and Prastowo (2019) reported that Japanese quail hens stocked at 221 cm^2/ bird produced heavier eggs than those stocked at 200 cm^2/ bird while quail hens kept at a floor space of 221 or 250 cm^2/bird gave similar egg weights. In addition, Ratriyanto *et al.* (2020) recommended that the best SD for Japanese quails is 45 birds per m^2 (222.2 cm^2/bird), combined with ascorbic acid supplementation (250 mg/kg), when reared in a hot climate. In line with our results, Reda *et al.* (2021) reported that egg number, egg weight and egg mass of Japanese quail hens were significantly decreased due to increasing SD from normal cage SD (36 quails/m^2) to high cage SD (60 quails/m^2). Similarly, Ahmed *et al.* (2022) demonstrated that as cage SD increased (from 252.20 to 106.73 cm^2/ bird) for Japanese quail hens their egg production rate, total egg mass and FCR were adversely affected. Generally, it has been reviewed that stress induced by increasing SD for different classes of poultry negatively affects their performance, physiological indices and the quality of their products (Gül *et al*., 2022). It seems that the optimal rates of SD of poultry depend on some factors such as season, species, gender, type of production (broiler chicks *vs.* laying hens), housing system (battery cages *vs.* floor pens) and housing conditions (open houses *vs.* environmentally controlled houses). In this regard, El-Sheikh *et al.* (2016) concluded that housing Japanese quail hens in floor pens beneficially affected their performance and egg quality compared with battery cages.

Table 2. Productive performance of Japanese quail kept at three stocking densities (SD) and fed diets with two levels of nutrient density (ND) from 7-19 weeks of age

Main effects:	ILBW[1] (g)	FLBW[2] (g)	HDEPR[3] (%)	EW[4] (g)	DFI[5] (g)	DEM[6] (g)	FCR[7] (g:g)
Cage SD (A):							
A1 (277.8 cm^2/bird)	254	272	53.60^a	13.39	39.23^a	7.165^a	5.530
A2 (208.3 cm^2/bird)	256	290	45.56^b	13.23	28.53^b	6.036^b	4.884
A3 (166.7 cm^2/bird)	248	282	38.47^b	13.05	23.91^c	5.009^c	4.841
SEM	2.716	10.61	2.045	0.0926	0.3454	0.2747	0.2710
P value	0.1256	0.4761	0.0002	0.0559	0.0001	0.0001	0.1607
Feed ND (B):							
B1 = NND (100%)	259	279	42.78^b	13.24	29.84^b	5.675^b	5.337
B2 = HND (105%)	257	283	48.96^a	13.20	31.27^a	6.465^a	4.833
SEM	2.218	8.663	1.670	0.0756	0.2820	0.2243	0.2213
P value	0.196	0.7153	0.0175	0.7298	0.0022	0.0227	0.1250

For each of the main effects, means within the same column having different superscripts differ significantly ($P\leq0.05$).
[1-7]: Denotes to initial and final live body weights, hen-day egg production rate, egg weight, daily feed intake, daily egg mass and feed conversion ratio.
SEM: Refers to the standard error of the means. NND: Normal nutrient density, HND: High nutrient density.

It is well-known that providing an optimal concentration of dietary bio-available nutrients is a critical item for different classes of poultry in order to minimize eco-pollution, feed cost and the undigested part of nutrients, thereby improving poultry performance and welfare. The observed improvement in HDEPR, DFI and DEM of Japanese quail hens in the present study following to feeding HND diets agrees with those of Ratriyanto *et al.* (2017). They indicated that Japanese quail hens fed high dietary CP levels (18 or 19.5%) displayed superior means of egg weight and egg mass to those fed low-CP diet (16.5%) but FCR improved only when quail hens were fed the highest-CP diet (19.5%), while FI and EPR were not affected. In a later study, Lotfi *et al.* (2018) found that egg production rate was significantly higher in Japanese quails fed diets with high levels of ME (12.77 MJ/kg diet) and CP (22%) than that of quails fed diets with lower levels of ME (11.51, 12.41 MJ/kg) and CP (18 and 20%). In addition, Hanafy and Attia (2018) pointed out that egg production rate, EW, DEM, DFI and FCR of Japanese quail hens were not influenced by dietary CP levels (18 and 20%) from 14 to 28 weeks of age. Recently, Widyas *et al.* (2019) suggested that laying Japanese quails fed diets with different ND displayed minor differences in egg production. In agreement also with the present results, DePersio *et al.* (2015) reported that feeding laying hens increasing energy and nutrient dense diets will increase egg production, egg weight, egg mass, feed efficiency and energy intake. Similarly, Khatibi *et al.* (2021) found that increasing dietary ND for laying hens to 102% increased productive performance but DFI was not affected. Under Egyptian summer conditions, Ismail *et al.* (2015) concluded that increasing dietary ND to 110% of the nutrient requirements of laying hens does not improve their productive performance.

Egg Quality of Japanese Quail:

Egg quality parameters of 15-wk-old quails as influenced by rates of SD and dietary ND are presented in Table 3. Apart from dietary ND, most egg quality traits investigated (egg weight and its components, egg shape index, yolk color score and Haugh units) were not significantly affected by cage SD of Japanese quail hens. However, the yolk index (YI) was deteriorated while shell thickness (ST) improved when cage SD increased to 166.7 cm^2/ bird. But dietary ND did not affect the egg quality of quails, measured herein (Table 3). There were no significant interactions between cage SD and dietary ND on all criteria of egg quality of quails, so the means of interaction were omitted. The observed improvement in ST of quail hens stocked at 166.7 cm^2/bird compared with those stocked at 277.8 cm^2/bird, in this study, might be resulted from the obvious reduction in HDEPR of the former than the latter (Table 2).

Table 3. Egg quality (EQ) parameters of 15-wk-old Japanese quail kept at three stocking densities (SD) and fed diets with two levels of nutrient density (ND)

Main effects:	Egg and its components				Exterior EQ		Interior EQ		
	EW[1](g)	SW[2](%)	YW[3](%)	AW[4](%)	ESI[5](%)	ST[6](mm)	YCS[7]	YI[8](%)	HU[9]
Cage SD (A):									
A1 (277.8 cm^2/bird)	12.27	12.58	31.94	55.47	78.11	0.274[b]	6.07	36.51[a]	86.83
A2 (208.3 cm^2/bird)	12.87	12.66	31.42	55.92	78.53	0.292[ab]	5.50	34.60[b]	86.72
A3 (166.7 cm^2/bird)	12.87	12.15	31.30	56.56	77.31	0.311[a]	5.80	34.48[b]	86.03
SEM	0.2641	0.2052	0.8410	0.8534	0.5733	0.0094	0.2026	0.5325	0.7748
P value	0.1852	0.1662	0.8469	0.6677	0.3125	0.0248	0.1476	0.013	0.7288
Feed ND (B):									
B1 = NND (100%)	12.91	12.49	30.96	56.55	78.26	0.295	5.98	35.43	85.95
B2 = HND (105%)	12.42	12.44	32.14	55.42	77.71	0.289	5.60	34.96	87.10
SEM	0.2156	0.1675	0.6867	0.6968	0.4681	0.0077	0.1654	0.4348	0.6326
P value	0.1126	0.821	0.2269	0.2551	0.4062	0.5684	0.1101	0.4421	0.2029

For each of the main effects, means within the same column having different superscripts differ significantly ($P \leq 0.05$).

[1-9]: Denotes to egg weight, shell weight, yolk weight and albumen weight, egg shape index, shell thickness, yolk color score, yolk index, Haugh units. SEM: Refers to the standard error of the means. NND: Normal nutrient density, HND: High nutrient density.

The observed improvement in ST of Japanese quails following increasing the cage SD from 277.8 to 166.7 cm^2/ bird, in this study, disagrees with the results of El-Tarabany *et al.* (2015) they reported that increasing cage SD for Japanese quails from 200 to 143 cm^2 per bird depressed their exterior and interior parameters of egg quality. In a later study, El-Tarabany (2016) found that laying quails kept at 200 cm^2/bird exhibited significantly better means of interior traits of egg quality than those of quails kept at higher cage SD (167 or 143 cm^2/bird). Our results, however, are in line with those reported by Bourdon *et al.* (2021) they evaluated the effects of four cage SD (112.2, 102.0, 93.5 and 86.3 cm^2/bird) on egg quality parameters of laying Japanese quails and found that eggshell quality criteria were not affected by different cage SD applied. However, Ratriyanto *et al.* (2020) found significant reduction in ST with increasing cage SD from 40 to 50 quails/ m^2. The inconsistent results that appeared in the scientific literature on egg quality parameters of Japanese quail hens kept at various SD may be related to variations in rates of SD, housing system, period of study or severity of overcrowding.

In disagreement with the present results, Wu *et al.* (2007) stated that as ND increased Haugh unit linearly reduced but weights of yolk and albumen significantly increased simultaneously, resulting in a significant increase in EW during early egg production of Leghorn strains of chickens. In a later study, Ismail *et al.* (2015) demonstrated that increasing dietary ND up to 110% for Bovans White laying hens led to significant improvements in ST, YI, Haugh units, egg albumen percent but relative weights of eggshell, egg yolk, egg shape index and yolk color score were not affected. Similarly, Lotfi *et al.* (2018) demonstrated that increasing dietary energy and protein levels for laying Japanese quails led to significant increases in egg shell thickness, egg shell strength and albumen and yolk indices. With laying hens, Panda *et al.* (2012), detected no benefits to increasing dietary ND to 7.5 % on the relative weights of egg components, shell thickness, yolk color score or Haugh units. However, DePersio *et al.* (2015) reported that feeding laying hens increasing energy and nutrient dense diets produced inconsistent responses in egg quality traits. Recently, Khatibi *et al.* (2021) found that increasing dietary ND for laying hens to 102% did not significantly affect eggshell thickness, Haugh unit and solid percentage.

Carcass Measurements of Quails:

Cage SD and dietary ND effects on carcass characteristics of 19-wk-old Japanese quail kept at three levels of SD and fed diets with two levels of ND are summarized in Table 4. It was observed that the relative weights of carcass yield (CY), individual giblets (*i.e.* liver, heart and gizzard), total giblets (TGI), total edible parts (TEP) and inedible parts (IEP) of Japanese quail hens were not significantly affected ($P>0.05$) by either cage SD or dietary ND applied. The interactions between cage SD and dietary ND did not significantly affect ($P>0.05$) all criteria of carcass traits of laying Japanese quail; therefore, their means were not tabulated.

The insignificant effect of cage SD on all carcass characteristics of laying Japanese quail, observed in this study, agrees with the results of Attia *et al.* (2012) they observed no beneficial effect on stocking density (166.7 *vs.* 83.3 cm^2/ bird) on carcass traits of growing quails. Similarly, El-Shafei *et al.* (2012) found that cage SD (233 vs. 140 cm^2bird) did not affect all carcass characteristics of laying Japanese quails except carcass yield which depressed significantly when SD increased from 233 to 140 cm^2/bird. In addition, Seker *et al.* (2009) observed that cage SD had no significant effect on carcass characteristics of growing Japanese quail. On the contrary, Beg *et al.* (2011) indicated that raising broiler chickens at high SD reduced their dressing percentage and increased abdominal fat pad. High SD (overcrowding) of broilers has been reported to decrease carcass yield (Kryeziu *et al.*, 2018; Madilindi *et al.*, 2018; Li *et al.*, 2019).

The lack of a positive effect of increasing the dietary ND for Japanese quail hens from 100% (the recommended level of the tested nutrients) to 105% on their carcass characteristics in the present study might be due to the fact that in laying quails dietary nutrients are mainly directed to egg production rather than growth (meat production). Alternatively, the applied range of dietary ND (100 to 105%) was too narrow to exert a beneficial effect under the condition of this study. Our results agree with those of Sherif *et al.* (2023) demonstrated that carcass characteristics were not influenced by dietary protein level (19.2, 21.6 and 24.0%) in growing Japanese quails. Similarly, Ashour *et al*. (2022) reported that pre-slaughter weight, carcass yield and dressing percentage of quails were not affected by protein levels of the diets (22, 24 and 26%) during the summer season but percent giblets reduced with increasing dietary protein level. The same authors noted that dressing percentage of quails decreased as dietary energy level increased from 2800 to 3000 kcal/kg but pre-slaughter weight and carcass yield were not affected.

Table 4. Carcass characteristics of 19-wk-old Japanese quail kept at three stocking densities (SD) and fed diets with two levels of nutrient density (ND)

Main effects:	LBW (g)[1]	CY (%)[2]	LI (%)[3]	HR (%)[4]	GZ (%)[5]	TGI (%)[6]	TEP (%)[7]	IEP (%)[8]
Cage SD (A):								
A1 (277.8 cm^2/bird)	281	69.78	2.16	0.79	1.43	4.37	74.15	25.85
A2 (208.3 cm^2/bird)	284	71.11	2.23	0.73	1.56	4.52	75.63	24.37
A3 (166.7 cm^2/bird)	268	69.70	2.41	0.78	1.55	4.73	74.43	25.57
SEM	7.666	0.524	0.101	0.026	0.051	0.129	0.564	0.564
P value	0.3341	0.1148	0.2141	0.210	0.129	0.144	0.1575	0.1575
Feed ND (B):								
B1 = NND (100%)	281	70.30	2.32	0.79	1.45	4.57	74.87	25.13
B2 = HND (105%)	274	70.10	2.20	0.74	1.57	4.51	74.61	25.39
SEM	6.259	0.428	0.083	0.021	0.042	0.105	0.461	0.461
P value	0.4024	0.740	0.2971	0.1422	0.3364	0.7223	0.6974	0.6974

[1-8]: Denotes to live body weight, carcass yield, liver, heart, gizzard, total giblets, total edible parts and inedible parts, respectively. SEM: Refers to the standard error of the means. NND: Normal nutrient density, HND: High nutrient density.

Blood Biochemical Parameters of Japanese Quail:

Blood serum parameters of 19-wk-old Japanese quail hens as affected by rates of SD and dietary ND are presented in Table 5. It was noted that most blood biochemical parameters of Japanese quail hens, measured in this study, were not significantly affected ($P>0.05$) by either cage SD or dietary ND. Inconsistent significant differences in serum levels of MDA ($P<0.01$) and COR ($P<0.05$) of quail hens in response to increasing cage SD from 277.8 to 166.7 cm^2/ bird, regardless of dietary ND. Also, as cage SD increased serum P concentration of quail hens significantly increased ($P<0.05$). However, as dietary ND increased serum LDL-C concentration of quail hens significantly increased ($P<0.01$) while serum level of UA significantly decreased ($P<0.05$), irrespective level of cage SD. The interactions between cage SD and dietary ND insignificantly affected ($P>0.05$) all blood parameters of quail hens at 19 weeks of age; therefore their means were not tabulated.

Table 5. Blood serum parameters of 19-wk-old female Japanese quails kept at three stocking densities (SD) and fed diets with two levels of nutrient density (ND)

Blood Parameters	Main effects:								
	Cage SD (cm^2/bird: A)					Feed ND (%: B)			
	A1 277.8	A2 208.3	A3 166.7	SEM	P Value	NND (100)	HND (105)	SEM	P Value
TP: g/dL	5.645	5.607	5.545	1.139	0.8233	5.707	5.490	0.930	0.1169
Alb: g/dL	2.766	2.604	2.696	0.789	0.3654	2.673	2.704	0.645	0.7413
Glo: g/dL	2.878	3.003	2.849	1.463	0.7347	3.034	2.786	1.194	0.1605
UA: mg/dL	3.052	2.770	2.838	1.018	0.1516	3.020[a]	2.753[b]	0.831	0.0360
Tri: mg/dL	179.9	179.2	177.8	3.292	0.9009	178.8	179.2	2.688	0.9243
TC: mg/dL	209.1	209.2	208.9	3.610	0.9978	210.8	207.4	2.948	0.4170
HDL-C: mg/dL	40.98	41.76	39.63	1.576	0.6352	40.92	40.66	1.287	0.8843
LDL-C: mg/dL	88.51	90.04	91.22	1.612	0.5052	86.49[b]	93.35[a]	1.316	0.0017
TAC: µmol/L	426.0	426.3	424.3	2.598	0.8485	425.5	425.6	2.1211	0.9664
MDA: µmol/L	1.173[a]	0.989[b]	1.077[ab]	0.374	0.0101	1.069	1.090	0.3056	0.6289
COR: pg/mL	3.713[ab]	3.975[a]	3.281[b]	0.166	0.0272	3.752	3.561	0.136	0.3353
P: mg/L	40.91[b]	40.39[b]	44.59[a]	0.974	0.0135	41.58	42.35	0.7953	0.4998
Ca: mg/L	54.57	55.03	53.83	1.545	0.8583	52.81	56.14	1.2611	0.0782
ALT: U/L	65.66	67.18	65.88	1.112	0.5899	65.99	66.49	0.9083	0.7036
AST: U/L	57.11	55.68	58.12	1.033	0.2683	57.19	56.75	0.8436	0.7158
ALP: U/dL	7.687	7.716	7.584	1.511	0.8123	7.630	7.694	1.2340	0.7186

[a-b]: For each of the main effects, means within the same row bearing different superscripts differ significantly ($P\leq0.05$). SEM: Standard error of the means.

Interestingly, the peruse of various reports appeared in scientific literature proves the occurrence of inconsistent responses of laying quails to cage SD with regard to blood biochemical parameters. In this regard, El-Shafei *et al*. (2012) found that increasing cage SD for laying Japanese quail (from 233 to 140 cm^2bird) significantly depressed plasma total protein fractions but increased levels of total lipids, cholesterol, total Ca and P phosphorous and activity of alanine aminotransferase (ALT) in blood plasma while levels of HDL-C and LDL-C and activity of aspartate aminotransferase (AST) were not affected. While Fahmy *et al*. (2005) reported that increasing SD of quail resulted in a decrease in blood AST and levels of testosterone and estradiol hormone and a significant increase in total lipids. Asghar Saki *et al*. (2012) observed no changes in plasma concentration of total cholesterol in laying hens due to increasing cage SD but levels of UA and Ca were decreased as the number of hens per cage increased. However, Bahşi *et al*. (2016) demonstrated that quails stocked at a floor space of 100 or 150 cm^2/bird displayed no significant differences in serum concentrations of glucose, total cholesterol, and high and low-density lipoproteins.

The lack of significant effects of dietary ND on most blood parameters of laying quails, estimated herein, agrees with those of Oh *et al*. (2012) they observed no significant effect of dietary protein (18, 20, 22 and 24%) on blood levels of glutamic-oxaloacetic transaminase, glutamic-pyruvic transaminase, blood urea nitrogen, albumin, and creatinine of Japanese quail hens. Similarly, Ismail *et al*. (2015) found that feeding the high nutrient density diets (102.5, 105, 107.5 and 110%) had no significant effect on most blood parameters of laying hens. In Japanese quail hens, Hanafy and Attia (2018) reported that blood plasma concentrations of total protein (TP), albumin and urea were not affected by dietary protein level (18 *vs*. 20%) but the activity of superoxide dismutase (SOD) was significantly depressed. On the other hand, Panda *et al*. (2012) indicated that the humoral immune response of laying hens as measured by antibody titer to sheep erythrocyte (estimated at 34 and 40 weeks) was progressively improved by increasing the nutrient density up to 5%; but when the dietary level of ND exceeded 5% no further improvement was observed.

CONCLUSION

Based on the obtained results, an optimal SD for laying Japanese quail is suggested to be 277.8 cm^2/ hen for normal productive performance, egg quality and blood parameters. Increasing dietary ND can alleviate the negative effect of high SD on the laying performance of quail hens.

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تـاثير كثافة التسكين وكثافة العناصر الغذائية على الاداء الإنتاجي وجودة البيض وصفات الدم للسمان الياباني

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الملخص

أجريت هذه الدراسة لمعرفة تأثير كثافة اسكان الطيور في البطاريات وكثافة العناصر الغذائية على الاداء الإنتاجي وجودة البيض وصفات الذبيحة وصفات الدم البيوكيميائية للسمان الياباني. تم توزيع ٢٨٨ طائر من السمان الياباني عمر سبعة اسابيع الى ستة مجاميع تجريبية (كل مجموعة في اربعة مكررات) تم تطبيق ثلاثة كثافات اسكان هي: ٢٧٧,٨، ٢٠٨,٣ ، ١٦٦,٧ سم٢ /طائر. تم تغذية ثلاثة مجاميع تجريبية على الاحتياجات الغذائية الطبيعية (١٠٠% من الاحتياجات الغذائية للسمان البياض) والثلاثة مجاميع الاخرى تم تغذيتها على ١٠٥% من الاحتياجات الغذائية (كثافة العناصر الغذائية) واستمرت التجربة اثنى عشر اسبوع من ٧- ١٩ أسبوع من عمر الطيور. أوضحت النتائج المتحصل عليها الاتي: لم تتأثر صفات الذبيحة ومعظم قياسات الدم والآداء الإنتاجي (وزن الجسم – وزن البيضة – الكفاءة التحويلية للغذاء) للسمان الياباني بكلا من كثافة الاسكان او كثافة العناصر الغذائية. زيادة كثافة الاسكان أثرت سلبيا على معدل انتاج البيض واستهلاك العلف اليومي وانتاج البيض اليومي لإناث السمان. زيادة كثافة العناصر الغذائية أدت إلى تحسن معدل انتاج البيض وإستهلاك العلف اليومي وإنتاج البيض اليومي لكنها لم تؤثر على باقي قياسات جودة البيض لإناث السمان. معظم قياسات جودة البيض (وزن البيضة – أجزاء البيضة - دليل شكل البيضة – لون الصفار – وحدات هوف) لم تتأثر بكثافة الإسكان بينما دليل الصفار انخفض وتحسن سمك القشرة بزيادة كثافة الإسكان. لوحظ إختلافات معنوية غير واضحة في محتوى السيرم من المالوندالدهيد والكورتيكوستيرون وزيادة معنوية فى محتوى السيرم من الفسفور لإناث السمان التي تعرضت لكثافة إسكان عالية. زيادة العناصر الغذائية أدت إلى زيادة محتوى السيرم من ليبوبروتين الكوليسيرول منخفض الكثافة وانخفاض محتوى السيرم من حامض اليوريك. التفاعل بين كثافة الاسكان في البطاريات وكثافة العناصر الغذائية لم تؤثر معنويا على كل القياسات المأخوذة بالنسبة للسمان اليابانى البياض. يمكن اقتراح أن كثافة إسكان السمان الياباني في البطاريات تكون ٢٧٧,٨ سم٢ /للطائر للحصول على أداء إنتاجي طبيعي وجودة البيض وقياسات الدم. زيادة كثافة العناصر الغذائية تخفف التأثير السلبى لكثافة الاسكان العالية على الآداء الإنتاجي للسمان الياباني البياض.