R. Bras. Zootec., 49:e20190049, 2020
https://doi.org/10.37496/rbz4920190049

Non-ruminants
Full-length research article

Revista Brasileira de Zootecnia

Brazilian Journal of Animal Science
e-ISSN 1806-9290
www.rbz.org.br

Effects of stocking density and climate region on performance, immunity, carcass characteristics, blood constitutes, and economical parameters of broiler chickens

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Received: April 30, 2019
Accepted: September 1, 2019

How to cite: Gholami, M.; Chamani, M.; Seidavi, A.; Sadeghi, A. A. and Aminafschar, M. 2020. Effects of stocking density and climate region on performance, immunity, carcass characteristics, blood constitutes, and economical parameters of broiler chickens. Revista Brasileira de Zootecnia 49:e20190049.
https://doi.org/10.37496/rbz4920190049

ABSTRACT - This experiment was conducted to evaluate the effects of stocking density and climate region on performance, immunity, carcass characteristics, blood plasma, and economic parameters of the Ross strain of broiler chickens. The effects of four climates (mild and humid, semi-arid, alpine, and hot and dry) and four densities (10, 15, 17, and 20 chicks/m^2) were studied as a completely randomized design with 4×4 factorial arrangement of treatments. The results showed that the density had a significant effect on feed intake and feed conversion ratio in the starter period and on body weight gain in the grower and the whole periods of the experiment. Moreover, both climate and density had a significant impact on economic performance (live weight, survival rate, production index, meat production/m^2, and profitability). The mild and humid climate and the density of 17 chicks/m^2 had the most economic benefit compared with other treatments. The climate type had a significant effect on the relative weights of the breast, wings, neck, proventriculus, and ileum. The effects of climate and density on glucose, triglyceride, very low-density lipoproteins (VLDL), high-density lipoproteins (HDL), LDL/low-density lipoproteins (HDL), total protein and globulin were significant. In addition, the effect of climate on the antibody titer against sheep red blood cells (except for immunoglobulin G on day 28) was significant.

Keywords: blood plasma, chick, climate, density, feed conversion ratio, immunity

Introduction

The world's population is expected to reach 15.9 billion by 2050 (Costantino et al., 2018). Therefore, the increasing population size and demand for animal proteins, especially broiler chicken white meat, are such that the development of the poultry industry and improvement of the production level are necessary to provide the protein requirements (Amini et al., 2015). One of the problems in broiler breeding is the low performance of the progeny than that expected. This factor is related to nutrition and method of feeding, strain selection, stocking density, sensitivity to pathogens and metabolic disorders, appropriate slaughter age, breeding climate, and other managerial and economic aspects (Hughes, 2012; Attia and Hassan, 2017; Attia et al., 2018).

Many variables such as environmental factors (climate and stocking density) can affect nutrition efficiency (Gharaghani et al., 2015; Attia et al., 2016). Different criteria are used for stocking density in different parts of the world (FAO, 2014). The most commonly used density is 30-42 kg live weight/m^2 and 30 kg live weight/m^2 in warm climate (Qaid et al., 2016). According to Attia et al. (2016), Arbor Acres and Hubbard strains in warm climate showed a significant increase in body weight, feed intake, feed conversion ratio, carcass performance, and meat quality. In addition, the performance of Arbor Acres chicks was better than the Hubbard strain.

The density/m^2 is variable based on slaughter age, access to free space, type of breed, and so on (Van Horne and Bondt, 2014), varying from 11 to 20 chicks/m^2 (Van Horne and Bondt, 2014). The total final body weight per area unit can be influenced by stocking density as determined by economic conditions and market demand (Imaeda, 2000). Controlling climatic conditions is costly for improving the welfare and performance of birds in different climates (Costantino et al., 2018). Awad et al. (2017) stated that feeding broiler chickens with enriched diets in controlled warm weather improved performance, the proportional weight of liver and abdominal fat, and blood parameters. In ostriches, it has been shown that warm and dry and temperate and humid climates have better effects than alpine climate on fertility (Bouyeh et al., 2017). However, egg production was not significantly different in warm and dry or temperate and humid climates.

Overall, the benefits of increasing stocking density are improved productivity, better use of limited available area, and increased income. Poultry husbandry is common in various climates, but it is unclear what climates are better for future development or what density is better in any specific climate.

Due to inadequate number of studies on the selection of suitable density in different climates or the combined effect of density and climate on the performance of broiler chickens, this study was carried out to address this problem. Our main objectives were to study growth performance, economic efficiency, carcass quality, blood parameters, and immunity of broiler chickens in four different climatic conditions with different densities and determine the most suitable density in each climate to maximize profits in different climatic conditions.

Material and Methods

The experimental protocol was ratified by the local Animal Ethics Committee in Tehran, Iran, and the experiment was performed with respect to the International Guidelines for research involving animals (Directive 2010/63/EU).

In this experiment, there were four stocking densities (10, 15, 17, and 20 chicks per m^2) and four climates (mild and humid, semi-arid, alpine, and hot and dry) with annual rainfall categories according to Kaviani and Alijani (2001), with four replications per treatment. Rainfall of more than 400 mm/year for locations as Sari, Amol, GhaemShahr, and Babol is labeled as mild and humid climate; between 250-400 mm/year for locations as Sabzevar, Nishapur, Torbat Heydariyeh, and Torbat-e-Jam is called alpine climate; between 150-250 mm/year for locations as Ardabil, MeshginShahr, Namin, and Niris known as semi-arid climate; and less than 150 mm/year for locations as Ardesta, Nain, Isfahan, and Shahin Shahr is defined as dry climate. A summary of geographic climates (geographical coordinates, average annual temperature (°C), average annual rainfall (mm), and altitude from the sea (m)) and the locations of study (longitude/E, latitude/N and height/m) as well as their tests are presented (Tables 1 and 2).

The area of each replicate pen was 20 m^2, so that each pen had a density of 10, 15, 17, and 20 containing 200, 300, 340, and 400 chicks, respectively. Thus, a total of 79,360 newly hatched Ross 308 broiler chicks were used in this experiment (200 + 300 + 340 + 400 = 1,240 chicks in the first replications and 4 × 4 × 4 × 1,240 = 79,360 overall) (Table 3).

The experimental period in all locations was six weeks (42 days), and all birds had free access to feed and water throughout the experiment. The diet was formulated according to requirements of Ross 308 (Table 4). The temperature within the pens was 31 °C in the first week and then reduced by 2 °C a week to reach a constant temperature of 25 °C. The humidity in the pens was 55%, and the lighting program was adjusted for 23 h light and 1 h darkness. The vaccination program and other management conditions were performed according to standard instructions for Ross 308 strain. Evaluation of performance characteristics was undertaken according to standard methods (Poorghasemi et al., 2013).

Weighing of chickens were performed on a weekly basis. This procedure was carried out by calculating the difference of weight between the beginning and end of each period in conjunction with wasted birds during a time range. Then, the result was divided by the bird per day. In addition, the extra weight of birds was determined for the following durations: starter (1-21 days), grower (22-42 days), and finisher (1-42 days) (Poorghasemi et al., 2013).

Table 1 - Geographical characteristics of the four climates studied

Climate	Rainfall (mm/year)	Geographical coordinates		Average annual temperature (°C)	Average annual rainfall (mm)	Altitude from the sea (m)
		Longitude/E	Latitude/N			
Mild and humid	More than 400	53.30	31.32	17.9	789.2	48
Semi-arid	Between 250-400	59.38	36.39	14.3	250	1,077
Alpine	Between 150-250	48.12	38.22	9.2	295.5	1,294
Hot and dry	Less than 150	51.33	32.48	16.3	125	1,600

Table 2 - Specifications of test site in 16 cities

City	Longitude/E	Latitude/N	Height (m)
Sari	53° 3' 31.547''	36° 33' 58.023''	42
Amol	52° 21' 4.471''	36° 28' 11.336''	94
Ghaem Shahr	52° 51' 29.666''	36° 27' 48.835''	60
Babol	52° 40' 36.427''	36° 32' 20.838''	4
Sabzevar	57° 40' 35.339''	36° 12' 45.308''	974
Nishapur	58° 47' 49.171''	36° 12' 40.683''	1,198
Torbat Heydariyeh	59° 13' 16.882''	35° 16' 56.654''	1,365
Torbat-e-Jam	60° 37' 31.423''	35° 14' 34.453''	909
Ardabil	48° 17' 39.329''	38° 14' 49.231''	1,352
Meshgin Shahr	47° 40' 35.341''	38° 23' 52.545''	1,418
Namin	48° 28' 56.237''	38° 25' 34.572''	1,424
Nir	48° 0' 47.256''	38° 2' 9.844''	1,609
Ardestan	52° 22' 52.780''	33° 22' 43.282''	1,198
Nain	53° 4' 31.111''	32° 51' 17.826''	1,576
Isfahan	51° 40' 17.662''	32° 40' 19.585''	1,575
Shahin Shahr	51° 33' 11.087''	32° 51' 37.336''	1,592

Table 3 - Experimental treatments (simulated climate × stocking density)

Treatment	Climate	Density (chicks/m^2)
1	Mild and humid	10
2	Mild and humid	15
3	Mild and humid	17
4	Mild and humid	20
5	Semi-arid	10
6	Semi-arid	15
7	Semi-arid	17
8	Semi-arid	20
9	Alpine	10
10	Alpine	15
11	Alpine	17
12	Alpine	20
13	Hot and dry	10
14	Hot and dry	15
15	Hot and dry	17
16	Hot and dry	20

Bird per day = (number of duration days × number of live birds at the end of period) + number of days that wasted birds were alive during the experiment.

In addition, feed intake for each period was determined by subtracting the remaining of feed at the end of each period from the beginning of feed rationing. Furthermore, this procedure was performed for the entire period as well. It worth noting that bird per day was a basis for the calculation (Mousavi et al., 2015).

Conversion ratio at the end of each period was calculated by knowing the extra body weight and feed conversion ratio to each period as well as for the entire duration of the experiment (Poorghasemi et al., 2013).

Economic performance, including the meat production of live chick/m^2, feed and chick costs, total cost, income/m^2, profit/m^2, final body weight, survival rate, and production index, were measured for each separate experimental unit (pen).

Survival or immortality is calculated based on the following:

Number of live birds = number of birds at the beginning for each experiment unit – number of birds wasted and omitted

Percentage of survival or immortality = (number of live chickens/number of birds at the beginning) × 100

The price of 1 kg live weight was assumed to be $ 0.93 for the calculation of income. The cost of feed and one-day old chicks was also estimated as 80% of all production costs. The price of starter and grower diets was $ 0.37 and $ 0.35/kg, respectively.

Blood plasma components were measured by standard method (Jahanpour et al., 2013; Poorghasemi et al., 2017). At 42 days of age, one chick from each replicate was randomly selected. Blood sampling was performed from the wing vein, and samples were sent immediately to the laboratory to determine the values of biochemical parameters including lipids, glucose, enzyme, protein, and uric acid. To measure blood parameters, the kits of Pars Azmoun Company (Iran) were used. All mentioned measurements were carried out by the colorimetric method. Since blood serum proteins comprise the sum of albumins and globulins (fibrinogen remains in the clot and does not enter into the serum),

Table 4 - Feed ingredients of diets used during the starter and grower periods

Item	Starter period (1 to 21 d)	Grower period (22 to 42 d)
Ingredient (as fed) (g/kg)		
Corn	562	615.7
Soybean meal	365	308
Soybean oil	25	34
Dicalcium phosphate	17	15
Calcium carbonate	12	11
Salt	3	2.8
Methionine	3.5	2.5
Vitamin premix[1]	5	5
Mineral premix[2]	5	5
Lysine	2.5	1
Calculated analysis		
Digestible energy (MJ/kg)	12.5	13
Crude protein (g/kg)	203	185
Calcium (g/kg)	10	8.2
Phosphorus (g/kg)	4.8	4.1
Methionine and cystine (g/kg)	10	8.3
Lysine (g/kg)	13	10.6

[1] Vitamin A, 5000 IU/g; vitamin D3, 500 IU/g; vitamin E, 3 mg/g; vitamin K3, 1.5 mg/g; vitamin B2, 1 mg/g
[2] Calcium pantothenate, 4 mg/g; niacin, 15 mg/g; vitamin B6, 13 mg/g; Cu, 3 mg/g; Zn, 15 mg/g; Mn, 20 mg/g; Fe, 10 mg/g; K, 0.3 mg/g.

the total globulin concentration for each serum sample was obtained by subtracting total protein and albumin concentration from the same sample.

The immunity parameters were measured by using standard methods (Shabani et al., 2015). To investigate the status of immune system, the antibody titer against the sheep red blood cell antigen (SRBC) was measured. The antibody titer changes were investigated by injection of SRBC (2%) as a non-pathogenic antigen, in two turns. At 15 and 35 days of age, two birds were selected from each experimental unit, and 0.5 mL of red blood cell suspension (2%) (prepared from Razi Institute, Karaj, Iran), which was washed three times with a physiological serum, was injected into the wing vein. Seven days after injection (at 24 and 42 days of age), blood samples were taken from the birds. In both stages of blood sampling, only one bird was used. Blood samples were kept in the laboratory for one day, and then the blood serum was isolated at 1000 rpm for 10 min. At first, serum samples were placed in an oven for 30 min at 55 °C to neutralize the complement and avoid interference with anti-SRBC antibody. Microtiter hemagglutination was used to determine the titer. When interpreting samples, the logarithm to base 2 of the last image of hemagglutination was recorded as antibody titer. To measure IgG and IgM, which components are responses to the SRBC, the sensitive antibody to mercaptoethanol that represents IgM was calculated by isolating the resistant antibody to mercaptoethanol (IgG) and deducting this amount from total response (IgM = IgG – total response).

The carcass characteristics were evaluated by using standard methods (Saraee et al., 2014). At the end of the experiment, three birds with a weight close to the average body weight of the group were selected from each pen (12 birds from each treatment) and starved for 4 h before slaughter. All chickens were weighed before slaughter. Carcass components were measured with a digital scale (0.001 precision) and the relative weight (% of body weight [BW]) of each component was recorded.

The experiment was carried out as a two-factor factorial arrangement of treatments, including four climates (mild and humid, semi-arid, alpine, and hot and dry), four densities (10, 15, 17, and 20 chicks per m^2), and four replicate pens per treatment in a completely randomized balanced design. Data were arranged using Excel software and analyzed using SAS software (Statistical Analysis System, version 8.2) with Proc GLM procedure. Each broiler formed the experimental unit. Means were compared using Duncan's test at P≤0.05. The statistical model of the design was as follows:

$$X_{ijk} = \mu + A_i + B_j + AB_{ij} + e_{ijk},$$

in which Xijk = the record of each observation, μ = the mean, Ai = climate effect, Bj = effect of density, ABij = the interaction effect of climate and density, and eijk= error effect.

Results

The effect of climate on average body weight was not significant in any of the periods (P≥0.05), whereas the effect of stocking density on average body weight was significant in the grower and whole period (P<0.05). The highest body weight gain was observed at a density of 10 chicks per m^2 in both the grower (22-42 d) and the entire periods (1-42 d). The interactive effect between climate and density on average body weight was not significant (P≥0.05). However, treatment with 10 chicks per m^2 density in alpine climate showed the highest average body weight numerically in the whole period (Table 5).

Different climates did not have any effect on feed intake in either period (P≥0.05), although the effect of stocking density on feed intake was significant in the grower period (P<0.05). The highest feed intake in the starter period was in hot and dry climate and in the grower period, it was in alpine climate. The interaction effect between climate and density on feed intake was not significant (P≥0.05). The highest feed intake was observed in mild and humid climate with 10 chicks per m^2 density in the whole period (P≥0.05; Table 5). The effect of climate was not significant on feed conversion ratio (P≥0.05). The effect of stocking density on feed conversion ratio was significant in both starter and grower periods (P<0.05). The best feed conversion ratio in the whole period was recorded in semi-arid and alpine climates for 10 chicks per m^2 density (P<0.05). The interaction effect of climate and density on feed conversion ratio was not significant (P≥0.05; Table 5).

The effect of climate on average body weight was not significant at the end of whole experimental period (P≥0.05). Birds in 10 and 20 chicks per m^2 densities showed the highest and the lowest body weights, respectively. Effect of stocking density on the final body weight was significant (P<0.05). The interaction effect of climate and density on average body weight at the end of experimental period was not significant (P≥0.05), but the highest body weight at the end of experiment was related to 10 chicks per m^2 stocking density in the alpine climate (Table 6).

The effect of climate and density on the survival rate of broiler chickens was significant (P<0.05). The lowest mortality was observed in the mild and humid climate with a density of 17 chicks per m^2, and the highest mortality percentage, in the hot and dry climate with 15 chicks per m^2 density. The interaction effect of climate and density on mortality was significant (P<0.05). The lowest and highest mortality was in mild and humid and hot and dry climates, respectively.

The effect of climate and density on production efficiency index was significant (P<0.05). The interaction effect of climate and density on production efficiency index was not significant at the end of the whole experimental period (P≥0.05). The highest production index was recorded for 15 and 17 chicks per m^2 densities in mild and humid climate (P<0.05; Table 6).

Table 5 - Effect of climate and stocking density on body weight gain (BWG; g/chick/day), feed intake (FI; g/chick/day), and feed conversion ratio (FCR; g/g) of Ross 308 broilers in the starter, grower, and whole periods

Treatment		Starter (1 to 21 d)			Grower (22 to 42 d)			Whole (1 to 42 d)		
		BWG	FI	FCR	BWG	FI	FCR	BWG	FI	FCR
Climate	Mild and humid	41.56	53.89	1.29	81.61	168.7	2.07	61.58	111.3	1.80
	Semi-arid	41.65	54.35	1.30	80.38	167.0	2.08	61.01	110.7	1.81
	Alpine	41.68	53.98	1.29	80.52	167.7	2.09	61.10	110.8	1.81
	Hot and dry	41.69	54.49	1.30	79.91	166.2	2.08	60.80	110.3	1.81
P-value		0.97	0.67	0.87	0.13	0.13	0.90	0.13	0.21	0.90
Density (chick/m^2)	10	41.58	55.23a	1.33a	82.81a	166.5	2.01	62.20a	110.9	1.78c
	15	41.68	54.18ab	1.30ab	81.73ab	167.4	2.05	61.70ab	110.8	1.79bc
	17	41.62	54.04b	1.30ab	81.01b	168.0	2.07	61.32b	111.0	1.81b
	20	41.70	53.25b	1.27b	76.87c	167.7	2.18	59.29c	110.5	1.86a
P-value		0.98	0.0072	0.02	<0.0001	0.52	<0.0001	<0.0001	0.71	<0.0001
Mild and humid	10	41.23	54.07	1.31	83.43	169.3	2.03	62.33	111.7	1.79
	15	41.81	54.15	1.29	82.66	166.8	2.02	62.24	110.5	1.77
	17	41.18	54.35	1.32	83.51	168.6	2.02	62.35	111.5	1.78
	20	42.01	52.97	1.26	76.83	170.1	2.21	59.42	111.5	1.87
Semi-arid	10	41.66	56.17	1.35	83.15	164.4	1.98	62.40	110.3	1.76
	15	41.56	53.66	1.29	81.38	168.0	2.06	61.47	110.8	1.80
	17	41.98	54.00	1.28	79.77	168.9	2.12	60.87	111.4	1.83
	20	41.39	53.56	1.29	77.23	166.9	2.16	59.31	110.2	1.85
Alpine	10	41.24	56.17	1.36	84.10	165.3	1.96	62.67	110.8	1.76
	15	41.76	54.02	1.29	81.83	168.5	2.06	61.80	111.3	1.80
	17	41.77	52.66	1.26	80.35	168.8	2.10	61.06	110.7	1.81
	20	41.96	53.07	1.26	75.81	168.0	2.22	58.88	110.6	1.88
Hot and dry	10	42.20	54.51	1.29	80.56	166.9	2.07	61.38	110.7	1.80
	15	41.58	54.89	1.32	81.04	166.2	2.05	61.31	110.5	1.80
	17	41.55	55.16	1.33	80.42	165.7	2.06	60.99	110.4	1.81
	20	41.43	53.40	1.29	77.62	166.0	2.14	59.53	109.7	1.84
SEM		0.44	0.80	0.02	1.04	1.52	0.03	0.48	0.63	0.01
P-value		0.68	0.30	0.25	0.23	0.47	0.0472	0.57	0.78	0.28

SEM - standard error of the means.
a-c - Means within same column with different letters are significantly different (P<0.05).

The effect of climate and density on meat production based on live weight per m^2 was significant (P<0.05). At the end of the experiment, the interaction effect of climate and density on meat production based on live weight was not significant (P<0.05; Table 6). The analysis of variance results showed that treatments with 20 chicks per m^2 density in mild and humid areas had the highest meat production per m^2 (P<0.05).

In this study, the highest income was obtained numerically at a density of 20 chicks per m^2 under mild and humid climate treatments (P<0.05; Table 6).

The greatest cost caused by climate and density interaction effect was obtained in 20 chicks per m^2 density and mild and humid climate treatment (P<0.05; Table 6).

The highest profit was obtained in mild and humid climate (P<0.05). Besides, the effect of density on economic profit was significant, so that the highest profit was obtained in the density of 17 chicks per m^2 (P<0.05). The interaction effect of climate and density on meat production based on average profit of production period was not significant (P≥0.05). The highest economic profit was obtained numerically at a density of 17 chicks per m^2 under mild and humid climate, with a profit of $ 3.74 per m^2 (P<0.05). From this point of view, the most suitable stocking density in mild and humid, hot and dry, and alpine climates was 17 chicks per m^2, whereas in semi-arid climate, it was 15 chicks per m^2 (P<0.05; Table 6).

Table 6 - Effect of climate region and stocking density on economic parameters of Ross 308 broilers at 42 days of age

Treatment		BW (g/chick)	Survival (%)	EPI	PBW (kg/m²)	Cost ($/m²)	Income ($/m²)	Profit ($/m²)
Climate	Mild and humid	2629.3	95.73a	332.3a	38.91a	39.03a	41.69a	2.66a
	Semi-arid	2605.4	94.02b	321.9b	37.83b	38.87c	40.53b	1.66b
	Alpine	2609.0	94.00b	322.6b	37.81b	38.89b	40.52c	1.63c
	Hot and dry	2596.2	93.61c	319.3b	37.13c	38.75d	40.24d	1.49d
P-value		0.13	<0.0001	0.0032	<0.0001	<0.0001	<0.0001	0.05
Density (chick/m²)	10	2654.8a	94.35b	335.0a	25.04d	25.11d	26.84d	1.73c
	15	2634.3ab	94.00c	329.0ab	37.14c	37.63c	39.80c	2.16b
	17	2618.1b	94.69a	326.5b	42.14b	42.73b	45.16b	2.43a
	20	2532.7c	94.32b	305.7c	47.34a	50.07a	51.19a	1.12d
P-value		<0.0001	0.0004	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mild and humid	10	2660.4	95.28b	337.3	25.35	25.25g	27.16	1.91
	15	2657.0	95.58ab	341.2	38.09	37.55f	40.81	3.26
	17	2661.2	96.14a	341.4	43.49	42.87d	46.60	3.74
	20	2538.5	95.92ab	309.3	48.70	50.45a	52.18	1.73
Semi-arid	10	2663.7	93.78cde	336.7	24.97	25.01g	26.76	1.76
	15	2624.8	93.62def	325.0	36.86	37.64f	39.49	1.85
	17	2599.5	94.41c	319.5	41.72	42.86d	44.70	1.84
	20	2533.7	94.26cd	306.5	47.76	49.97b	51.18	1.21
Alpine	10	2674.6	94.18cd	339.7	25.19	25.10g	26.99	1.89
	15	2638.3	93.83cde	327.9	37.12	37.77f	39.78	2.02
	17	2607.2	94.08cd	322.4	41.69	42.62e	44.68	2.06
	20	2516.0	93.90cd	300.3	47.25	50.08b	50.63	0.54
Hot and dry	10	2620.3	94.15cd	326.0	24.67	25.08g	26.43	1.35
	15	2617.2	92.97f	321.8	36.50	37.57f	39.11	1.53
	17	2604.5	94.13cd	322.8	41.67	42.56e	44.65	2.10
	20	2542.7	93.20ef	306.6	45.67	49.78c	50.78	1.01
SEM		20.45	0.22	5.25	0.40	0.18	0.43	0.47
P-value		0.57	0.0088	0.3321	0.10	0.03	0.10	0.64

BW - body weight at the 42nd day of age; EPI - European production index; PBW - produced body weight in m^2; SEM - standard error of the means.
a-f - Means within same column with different letters are significantly different (P<0.05).

The effect of climate on the amount of glucose, triglyceride, total cholesterol, low-density lipoproteins (LDL):high density lipoproteins (HDL) ratio, HDL, very-low-density lipoprotein (VLDL), uric acid, aspartate aminotransferase (AST), alanine aminotransferase (ALT), total protein, and globulin content of blood plasma was significant (P<0.05; Tables 7 and 8), whereas the effect of climate on albumin was not significant (P<0.05; Table 8). Stocking density significantly affected levels of glucose, triglyceride, VLDL, HDL, total protein, and globulin (P<0.05) but did not affect total cholesterol, LDL, LDL/HDL ratio, uric acid, AST, ALT, and albumin (P≥0.05; Tables 7 and 8). The interaction effect of climate and density on total cholesterol, triglyceride, VLDL, HDL, LDL:HDL ratio, and globulin were significant (P<0.05).

At 28 d of age, different climates significantly affected the levels of IgM and total antibody, whereas at 42 d of age, it affected IgG, IgM, and total antibody (P<0.05; Table 9). The highest and lowest levels of response to antibody were observed in hot and dry and mild and humid climates, respectively (P<0.05). At 28 d of age, the total amount of antibody in 20 chicks per m^2 treatment under semi-arid climate and at 42 d of age in 10 chicks per m^2 treatment under alpine and hot and dry climates was higher compared with other treatments (P<0.05).

The effect of climate on live body weight, featherless body weight, full abdomen carcass weight, empty abdomen carcass weight, breast, wings, neck, and proventriculus as a percentage of featherless body weight was significant (P<0.05; Tables 10-12). Chickens reared under hot and dry climate had the

Table 7 - Effect of climate region and stocking density on plasma constitutes (lipids and glucose) of Ross 308 broilers at 42 days of age

Treatment		Glucose (mg/dL)	Total cholesterol (mg/dL)	Triglycerides (mg/dL)	VLDL (mg/dL)	HDL cholesterol (mg/dL)	LDL cholesterol (mg/dL)	LDL:HDL
Climate	Mild and humid	195.1ab	164.8a	61.18a	12.23a	73.82a	82.76b	1.12b
	Semi-arid	193.4bc	162.6b	60.15a	12.03a	72.76a	84.16ab	1.16b
	Alpine	197.4a	161.0b	61.79a	12.35a	68.61b	85.70a	1.25a
	Hot and dry	192.6c	161.1b	56.57b	11.31b	69.46b	84.38ab	1.22a
P-value		0.0003	0.0001	<0.0001	<0.0001	<0.0001	0.04	<0.0001
Density (chick/m^2)	10	192.9b	161.2	59.17a	11.83b	70.29b	84.03	1.20
	15	193.8b	162.6	58.74a	11.74b	70.43b	83.37	1.18
	17	194.7b	162.5	59.82a	11.96b	70.43a	84.75	1.17
	20	197.1a	163.1	61.97b	12.39a	71.60ab	84.85	1.19
P-value		0.0026	0.22	0.0091	0.0091	0.04	0.43	0.58
Mild and humid	10	190.4	163.9a-d	61.18b-e	12.23b-e	73.19abc	81.61	1.12de
	15	196.2	163.0a-d	57.81efg	11.56efg	72.49a-d	82.32	1.14cde
	17	195.8	165.6abc	63.04abc	12.60abc	75.16a	83.75	1.11de
	20	198.2	166.6a	62.69a-d	12.53a-d	74.44ab	83.35	1.12de
Semi-arid	10	193.7	161.9b-e	58.24d-g	11.64d-g	73.52abc	83.80	1.14cde
	15	192.9	165.8ab	59.56c-g	11.91c-g	69.90c-f	82.92	1.19bcd
	17	191.7	161.2de	56.00fg	11.20fg	75.46a	82.83	1.09e
	20	195.3	161.6b-e	66.81a	13.36a	72.18a-d	87.10	1.21a-d
Alpine	10	197.3	157.8e	59.04c-g	11.80c-g	67.65ef	87.26	1.29a
	15	194.5	160.6de	59.96c-f	11.99c-f	69.19def	84.34	1.22abc
	17	197.5	162.7a-e	64.68ab	12.93ab	67.58ef	87.26	1.29a
	20	200.2	163.1a-e	63.47abc	12.69abc	70.03c-f	83.94	1.20bcd
Hot and dry	10	190.2	161.4cde	58.21d-g	11.64d-g	66.80f	83.46	1.25ab
	15	191.5	161.2de	57.62eg	11.52efg	70.15c-f	83.90	1.19bcd
	17	193.9	160.5de	55.56fg	11.11fg	71.15b-e	85.15	1.19bcd
	20	194.9	161.2de	54.90g	10.98g	69.75c-f	85.00	1.22abc
SEM		1.66	1.31	1.44	0.28	1.18	1.44	0.02
P-value		0.30	0.03	<0.0001	<0.0001	0.05	0.34	0.02

VLDL - very low-density lipoprotein; HDL - high-density lipoproteins; LDL - low-density lipoproteins; SEM - standard error of the means.
a-f - Means within same column with different letters are significantly different (P<0.05).

highest empty abdomen carcass weight. Different densities significantly affected live body weight/ empty abdomen carcass weight, thighs, and proventriculus as a percentage of featherless body weight (P<0.05). The interaction effect of climate and density on proventriculus weight was significant (P<0.05). Experimental treatments with 20 chicks per m^2 in semi-arid climate had the highest ratio of proventriculus weight to featherless carcass weight (P<0.05; Table 12).

Discussion

As the results of this study showed, the effect of outdoor climate on average body weight gain, feed intake, and daily feed conversion ratio in starter, grower, and whole periods were not significant (P≥0.05). The reason is the development and evolutions of technology in the fundamental changes in the structure and management of poultry facilities, controlling environmental conditions and improving qualitative development. In this case, having an efficient ventilation system in broiler chicken houses to remove excess moisture and heat (especially in the warm seasons), dust, and hovering particles, as well as to provide oxygen and removing toxic gases is important (Karcher, 2009).

Broiler chickens consume a certain amount of energy per day and then stop eating, even if they have not received their required protein, minerals, and vitamins (Baghoyan, 2006). So, if the management technology of poultry facilities is not optimal, this balance will not be achieved.

Table 8 - Effect of climate region and stocking density on plasma constitutes (enzymes, proteins, and uric acid) of Ross 308 broilers at 42 days of age

Treatment		Uric acid (mg/dL)	AST (U/L)	ALT (U/L)	Total protein (g/dL)	Albumin (g/dL)	Globulin (g/dL)
Climate	Mild and humid	4.55b	295.2a	542.9b	3.96ab	1.14	1.37a
	Semi-arid	4.71b	296.0a	538.6b	3.87b	1.14	1.30b
	Alpine	5.18a	293.1b	556.3a	3.99a	1.13	1.26bc
	Hot and dry	4.50b	293.3b	534.2b	3.90ab	1.15	1.24c
P-value		0.0005	0.004	<0.0001	0.04	0.95	<0.0001
Density (chick/m^2)	10	4.75	294.4	538.8	3.88b	1.15	1.25b
	15	4.56	293.1	541.6	3.89b	1.13	1.29ab
	17	4.71	294.7	547.8	4.00a	1.17	1.33a
	20	4.93	295.4	543.8	3.95ab	1.12	1.30a
P-value		0.20	0.12	0.23	0.02	0.17	0.005
Mild and humid	10	4.08	294.9	533.9	3.93	1.15	1.37abc
	15	4.40	294.1	540.7	3.93	1.14	1.38ab
	17	4.60	297.1	557.1	4.03	1.20	1.41a
	20	5.13	294.8	540.0	3.94	1.09	1.32a-d
Semi-arid	10	4.68	296.2	541.2	3.77	1.14	1.26c-f
	15	4.59	294.8	541.1	3.76	1.15	1.33a-d
	17	4.75	295.0	538.2	4.03	1.18	1.35a-d
	20	4.84	298.0	533.9	3.93	1.10	1.26def
Alpine	10	5.09	292.2	561.3	3.98	1.14	1.20ef
	15	5.14	292.3	553.2	4.00	1.10	1.24def
	17	5.22	294.7	556.9	4.01	1.15	1.29b-e
	20	5.28	293.3	553.8	3.98	1.15	1.33a-d
Hot and dry	10	5.17	294.3	518.9	3.85	1.17	1.17f
	15	4.10	291.4	531.4	3.88	1.13	1.20ef
	17	4.27	291.9	539.1	3.93	1.15	1.28b-e
	20	4.47	295.5	547.5	3.96	1.13	1.31a-e
SEM		0.24	1.35	6.31	0.06	0.03	0.03
P-value		0.06	0.44	0.07	0.65	0.72	0.05

AST - aspartate amino transferase; ALT - alanine amino transferase; SEM - standard error of the means.
a-f - Means within same column with different letters are significantly different (P<0.05).

In a state of energy deficiency in the diet, body carbohydrates, fats, and proteins are catabolized (broken down) in body tissues, which leads to heat production (Lesson and Summers, 2008; Attia and Hassan, 2017; Attia et al., 2018). When the equipment of poultry facilities is not good, the effect of climate predominates on poultry house environment and the catabolism increases. According to the significant daily feed intake during the starter period and the increase of body weight gain during the grower and whole periods, the reason for this can be the greater floor space and feed trough allocated to each bird in 10 chicks per m^2 density compared with other treatments. Increasing stocking density causes increased stress, competition for feed intake, microbial activity, and ammonia gas production, which leads to weight loss (Galobart and Moran Jr., 2005). Besides, increasing stocking density causes increases in moisture content, incidence of dermatitis in foot pads, breast wounds, and skin problems, and as a result, reduces the carcass grading in the slaughterhouse (Kjaer, 2004). The significant effect of stocking density on feed conversion ratio during the starter and whole periods affected final body weight and the profit per m^2. In this study, the treatments with 17 chicks per m^2 density showed the highest profit per m^2. Poultry growth is a quantitative trait influenced by the genotype, environment, and contents of diet. Differences in performance can be attributed to the above-mentioned effects and the interaction effect of genotype and environment (FAO, 2014; Attia et al., 2016).

Table 9 - Effect of climate region and stocking density on immunity of Ross 308 broilers at 28 and 42 days of age

Treatment		28 days			42 days		
		TSRBC (IgG)[1]	TSRBC (IgM)[2]	TSRBC (IgT)[3]	TSRBC (IgG)[1]	TSRBC (IgM)[2]	TSRBC (IgT)[3]
Climate	Mild and humid	0.92	0.64b	1.56b	1.59b	1.46c	3.06c
	Semi-arid	0.92	1.10a	2.03a	2.01a	2.15b	4.17b
	Alpine	0.95	1.14a	2.09a	2.25a	2.64a	4.89a
	Hot and dry	0.95	1.14a	2.09a	2.25a	2.64a	4.89a
P-value		0.98	<0.0001	0.01	<0.0001	<0.0001	<0.0001
Density (chick/m^2)	10	1.00	0.93	1.93	1.98	2.32	4.31
	15	0.89	0.96	1.85	2.04	2.31	4.35
	17	0.90	1.04	1.95	2.03	2.14	4.17
	20	0.95	1.07	2.03	2.04	2.12	4.17
P-value		0.75	0.52	0.83	0.94	0.20	0.68
Mild and humid	10	0.87	0.56	1.43	1.56	1.56	3.12
	15	1.00	0.62	1.62	1.68	1.56	3.25
	17	0.93	0.68	1.62	1.62	1.43	3.06
	20	0.87	0.68	1.56	1.50	1.31	2.81
Semi-arid	10	0.87	0.93	1.81	2.00	2.25	4.25
	15	0.81	1.12	1.93	2.00	2.43	4.43
	17	0.93	1.12	2.06	2.00	1.87	3.87
	20	1.06	1.25	2.31	2.06	2.06	4.12
Alpine	10	1.12	1.12	2.25	2.18	2.75	4.93
	15	0.87	1.06	1.93	2.25	2.62	4.87
	17	0.87	1.18	2.06	2.25	2.62	4.87
	20	0.93	1.18	2.12	2.31	2.56	4.87
Hot and dry	10	1.12	1.12	2.25	2.18	2.75	4.93
	15	0.87	1.06	1.93	2.25	2.62	4.87
	17	0.87	1.18	2.06	2.25	2.62	4.87
	20	0.93	1.18	2.12	2.31	2.56	4.87
SEM		0.15	0.15	0.26	0.16	0.17	0.27
P-value		0.90	0.99	0.96	0.99	0.92	0.98

[1] Immunoglobulin G antibody against sheep red blood cell (SRBC); [2] immunoglobulin M antibody against SRBC; [3] total antibody against SRBC; SEM - standard error of the means.
a-c - Means within same column with different letters are significantly different (P<0.05).

Baéza et al. (2012) stated that the density of 17 chicks per m^2 had the highest profit per m^2. In another research study, Esmail (2013) showed that many factors (such as flock size, density, temperature, lighting, feed, water, etc.) affect growth rate, feed intake, and mortality in broiler chickens and, consequently, the production index. In the present study, the highest production index and meat production per m^2 were obtained in the mild and humid climate; moreover, the highest production efficiency index was obtained at 10 chicks per m^2 density. If the flock stocking density is high, under climates that cause heat stress, birds will consume less feed. When there is an imbalance of amino acids, nutrient deficiency can be severe (Ike, 2011; Attia and Hassan, 2017; Attia et al., 2018). Probably, nutrient deficiency due to lack of adequate feed intake is the reason for decreasing growth of broiler chickens in treatments with 20 chicks per m^2 density.

Birds have a high sensitivity to heat stress (Ojano-Dirain and Waldroup, 2002). This phenomenon reduces feed intake, growth, digestibility of amino acids and other nutrients, changes the amino acid requirements, as well as induces changes in carcass composition, and ultimately reduces performance, resulting in significant economic losses (Ezeh et al., 2012). One of the goals of this study was to determine the optimum stocking density in different climates. The results showed that, although the effect of climate and density on the production index was not significant, the highest production efficiency index numerically was obtained in mild and humid climate with a density of 17 chicks per m^2, which had the lowest mortality rate.

Table 10 - Effect of climate region and stocking density on carcass components of Ross 308 broilers at 42 days of age

Treatment		LBW (g)	DBW (g)	FACW (g)	EACW (g)	EC (%)
Climate	Mild and humid	2552.3ab	2341.6a	2142.4a	1626.8	75.99b
	Semi-arid	2560.6a	2333.8a	2124.1b	1609.1	75.82b
	Alpine	2557.3a	2334.2a	2115.5b	1611.3	76.24ab
	Hot and dry	2540.3b	2300.9b	2082.4c	1602.3	77.04a
P-value		0.04	<0.0001	<0.0001	0.09	0.01
Density (chick/m^2)	10	2545.4b	2323.4	2116.9	1610.8	76.17ab
	15	2564.8a	2339.2	2125.0	1621.1	76.37ab
	17	2555.7ab	2327.8	2116.8	1601.2	75.72b
	20	2544.6b	2320.2	2105.8	1616.4	76.84a
P-value		0.02	0.13	0.18	0.23	0.05
Mild and humid	10	2545.8	2332.7	2133.5	1620.2	75.98
	15	2556.0	2354.3	2150.5	1648.8	76.73
	17	2553.5	2329.7	2133.6	1591.7	74.67
	20	2553.8	2349.6	2151.8	1646.7	76.59
Semi-arid	10	2555.9	2326.0	2125.5	1603.2	75.50
	15	2582.9	2342.5	2132.6	1605.0	75.31
	17	2565.5	2350.8	2125.6	1631.4	76.81
	20	2538.0	2316.1	2112.7	1596.8	75.66
Alpine	10	2551.5	2326.5	2112.8	1612.5	76.39
	15	2561.2	2350.9	2131.4	1626.2	76.37
	17	2570.5	2334.1	2114.8	1586.9	75.13
	20	2546.2	2325.2	2103.0	1619.7	77.07
Hot and dry	10	2528.3	2308.3	2095.8	1607.5	76.79
	15	2559.3	2309.1	2085.4	1604.4	77.05
	17	2533.1	2296.3	2093.1	1594.9	76.28
	20	2540.3	2289.9	2055.5	1602.4	78.04
SEM		10.70	12.16	12.44	14.25	0.57
P-value		0.53	0.63	0.55	0.11	0.09

LBW - live body weight; DBW - defeathered body weight; FACW - full abdomen carcass weight; EACW - empty abdomen carcass weight; EC - eviscerated carcass; SEM - standard error of the means.
a-c - Means within same column with different letters are significantly different (P<0.05).

Begum et al. (2009), using data envelopment analysis (DEA) to evaluate economic efficiency on a poultry farm, found that the economic efficiency was less than technical efficiency. In addition, the results of their research showed that the highest profit was obtained due to the use of all capacities and the reduction of excess inputs in the density of 17 chicks per m^2. In this study, the density of 20 chicks/m^2 in hot and dry climate should not be recommended. Moreover, the most suitable stocking density in mild and humid, alpine, and hot and dry climates was 17 chicks/m^2, and 15 chicks/m^2 in semi-arid climate.

It may seem that chicken production will have more profit in 20 kg/m^2 density, whereas in our research, the optimum density for maximum profit was 17 chicks/m^2. Due to the small body size of chicks in the starter period, the greater competition for the necessary space, and less access to feed, the effect of density on body weight gain in this period was not significant ($P \geq 0.05$). However, in this research, because the chick body size was larger in the grower period and the competition for access to feed was higher, this factor made the meat production/m^2 significant ($P<0.05$). The meat production (kg meat/m^2) of each chicken in 20 chicks/m^2 was lower than in the other treatments, the cumulative income of treatments at a density of 20 chicks/m^2 was less than other treatments in whole period, and the treatments at a density of 17 chicks/m^2 had the highest profit.

The identification of optimal density in different climates for a specific product, such as chicken meat, provides the fields of policy-making development and orientation of government supportive policies in each climate, and can be a model for other areas of the world to maximize production. The sum

Table 11 - Effect of climate region and stocking density on relative weight of carcass components (% of defeathered weight) of Ross 308 broilers at 42 days of age

Treatment		% BR	% DR	% WN	% AFW	% GZ	% HR	% NC
Climate	Mild and humid	34.89a	31.40	4.31b	2.41	2.85	0.61	2.38b
	Semi-arid	33.84b	31.18	4.52a	2.52	2.88	0.62	2.39b
	Alpine	33.51b	31.37	4.49a	2.45	2.86	0.62	2.38b
	Hot and dry	34.23ab	31.81	4.54a	2.54	2.87	0.63	2.60a
P-value		0.01	0.25	<0.0001	0.21	0.95	0.46	<0.0001
Density (chick/m^2)	10	34.22	31.77a	4.51	2.49	2.88	0.61	2.43
	15	33.82	30.92b	4.46	2.55	2.80	0.63	2.41
	17	34.38	31.57ab	4.45	2.42	2.90	0.62	2.49
	20	34.06	31.50ab	4.44	2.46	2.88	0.61	2.42
P-value		0.60	0.05	0.59	0.27	0.29	0.54	0.34
Mild and humid	10	34.62	31.94	4.40	2.45	2.85	0.60	2.37
	15	34.91	30.93	4.28	2.46	2.89	0.64	2.35
	17	35.89	31.11	4.28	2.42	2.81	0.61	2.47
	20	34.14	31.63	4.28	2.33	2.86	0.60	2.34
Semi-arid	10	34.41	31.04	4.57	2.37	2.98	0.63	2.35
	15	32.84	30.76	4.61	2.58	2.72	0.63	2.42
	17	33.88	31.31	4.44	2.50	2.96	0.62	2.41
	20	34.25	31.59	4.47	2.62	2.88	0.61	2.37
Alpine	10	34.06	32.15	4.54	2.55	2.87	0.60	2.44
	15	33.18	31.16	4.41	2.55	2.88	0.61	2.32
	17	33.21	31.25	4.55	2.33	2.82	0.62	2.43
	20	33.59	30.93	4.47	2.38	2.88	0.63	2.32
Hot and dry	10	33.79	31.93	4.51	2.60	2.84	0.63	2.56
	15	34.36	30.84	4.56	2.61	2.72	0.64	2.55
	17	34.55	32.63	4.54	2.45	3.01	0.62	2.64
	20	34.24	31.83	4.56	2.50	2.90	0.62	2.64
SEM		0.60	0.45	0.06	0.09	0.07	0.01	0.06
P-value		0.46	0.41	0.52	0.58	0.25	0.84	0.85

BR - breast; DR - drumsticks; WN - wings; AFW - abdominal fat weight; GZ - gizzard; HR - heart; NC - neck; SEM - standard error of the means.
a-b - Means within same column with different letters are significantly different ($P<0.05$).

of final body weight per area unit is an effective factor in the profitability of productive unit, which, according to economic conditions and market demand, can affect the flock density per area unit decision and the average body weight for each bird (Begum et al., 2010). The results of this study showed that changing density from 10 to 17 chicks/m^2 will increase profit by $ 1.83 in mild and humid climate, $ 0.88 in semi-arid climate, $ 0.17 in alpine climate, and $ 0.75 in hot and dry climate. Thus, for example, under humid climate in a poultry replication with 2,000 m^2 area, increasing the density from 10 to 17 chicks/m^2 will yield $ 3,660 more profit in the whole period.

The mild and humid and hot and dry climates had the highest and lowest profitability, respectively (P<0.05). In fact, when birds are under heat stress condition, some changes occur in the blood system. The cardiovascular system involves heat removal, acid-base imbalance, increased blood pH, and respiratory alkalosis (Altan et al., 2000). It is known that stress causes disruption of leukocyte function in poultry (Ozbey et al., 2004).

Blood parameters such as triglyceride, total cholesterol, LDL:HDL, HDL, VLDL, and globulin ratios were significantly affected by climate and density (P<0.05). Moreover, chickens under alpine climate had the highest levels of blood glucose and total protein; however; chickens grown in semi-arid climate showed the lowest total protein content. These findings are consistent with the results of Zhang (2015), Attia and Hassan (2017) and Attia et al., 2018. In another report, increasing the temperature of quail breeding environment reduced the total serum protein (Ozbey et al., 2004); besides, Niu et al. (2009) indicated that high temperature weakens the immune system of broiler chickens.

Table 12 - Effect of climate region and stocking density on relative weight of carcass components (% of defeathered weight) of Ross 308 broilers at 42 days of age

Treatment		Back thoracic vertebrae	Crop	Proventriculus	Pancreas
Climate	Mild and humid	3.01	0.48	0.42b	0.29
	Semi-arid	3.05	0.49	0.42b	0.29
	Alpine	3.07	0.47	0.43ab	0.29
	Hot and dry	3.13	0.47	0.44a	0.28
P-value		0.06	0.46	0.05	0.77
Density (chick/m^2)	10	3.09	0.48	0.43a	0.29
	15	3.08	0.48	0.42b	0.29
	17	3.03	0.49	0.42ab	0.29
	20	3.06	0.47	0.43ab	0.28
P-value		0.59	0.63	0.04	0.31
Mild and humid	10	3.02	0.50	0.44a-d	0.28
	15	3.06	0.45	0.41de	0.29
	17	2.94	0.48	0.41cde	0.30
	20	3.01	0.49	0.42b-e	0.28
Semi-arid	10	3.05	0.51	0.43a-e	0.28
	15	3.07	0.46	0.40e	0.29
	17	3.03	0.52	0.41de	0.29
	20	3.04	0.48	0.45a	0.29
Alpine	10	3.14	0.47	0.44abc	0.30
	15	3.09	0.49	0.41cde	0.29
	17	3.02	0.48	0.42a-e	0.30
	20	3.02	0.45	0.42a-e	0.28
Hot and dry	10	3.14	0.44	0.43a-e	0.28
	15	3.09	0.49	0.45ab	0.29
	17	3.12	0.48	0.44a-d	0.28
	20	3.16	0.47	0.43a-d	0.28
SEM		0.06	0.02	0.01	0.00
P-value		0.95	0.33	0.01	0.84

SEM - standard error of the means.
a-e - Means within same column with different letters are significantly different (P<0.05).

In the present study, the final body weight of broiler chickens in simulated hot and dry climate was lower than in other climates, which resulted in the lowest income. This may be due to the increase in temperature leading to a decrease in absorption of essential and nonessential amino acids and of protein synthesis, and increase in bird catabolism, blood glucose, and glucocorticoid levels (Gous and Morris, 2005). Some researchers have shown that stocking density causes the suppression of the immunity of broiler chickens, which can easily be determined by evaluating the weight of Bursa of Fabricius and Bursa of Fabricius weight:body weight ratio during slaughter (Heckert et al., 2002). The results of this study showed that chicks reared at a density of 20 chicks/m^2 had the lowest immune response at 42 days of age. In another study, stocking density changed to 18 birds/m^2 did not have a significant effect on antibody titer against SRBC and on IgG and IgM titers (Heckert et al., 2002), which is consistent with our findings.

Palizdar et al. (2017) reported that stocking density significantly increased the immune response, including antibody titer against SRBC, IgG, and IgM. At high densities, the antibody titer against SRBC and the IgG and IgM titers were higher compared with low densities, which is not in agreement with the findings of the present study ($P<0.05$). In this study, antibody titer against SRBC was significant in different climates studied ($P<0.05$), in which alpine as well as hot and dry climates had the highest immune response and the highest defeathered carcass weight and were in second place in terms of profitability.

The amount of blood glucose increases during heat stress (Ozbey et al., 2004). High environmental temperature weakens the immune system of broiler chickens (Niu et al., 2009). One of the major problems in tropical regions is the reduction of feed intake, growth, digestibility of amino acids and other nutrients, and changes in amino acid requirements, as well as changes in carcass composition and eventually reduced performance (Senkoylu and Altinsoy, 1999; Attia et al., 2016; Attia and Hassan, 2017).

In this experiment, the ratio of proventriculus weight to defeathered carcass weight of broiler chickens grown at a density of 20 chicks/m^2 in semi-arid climate was higher than in other climates. The reason is the intensity of the competition of chickens for feed, which led to an enlarged proventriculus; however, the average final body weight of this group was lower compared withother climates.

Experimental treatments under mild and humid climate showed the highest production index. In this experiment, 17 chicks/m^2 in mild and humid climate showed the highest profit ($ 3.74/m^2) and the density of 20 chicks/m^2 in alpine climate showed the lowest profit ($ 0.54/m^2). Therefore, according to the purpose of this experiment, to achieve maximum profit in each climate, the appropriate density should be selected.

Conclusions

This study showed that the maximum profit was gained in mild and humid, alpine, or hot and dry climates at a density of 17 chicks/m^2 and in semi-arid climate at a density of 15 chicks/m^2. Moreover, the most achieved profit was in the mild and humid climate at a density of 17 chicks/m^2 compared with other climates and densities, and this group had the lowest mortality rate and the highest production index among experimental treatments. Broiler chickens grown in hot and dry climate have the highest, while those in mild and humid climate, the lowest levels of antibody response.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: M. Gholami and A. Seidavi. Funding acquisition: M. Gholami and A. Seidavi. Investigation: M. Gholami. Methodology: M. Gholami, M. Chamani, A. Seidavi, A.A. Sadeghi and M. Aminafschar. Project administration: A. Seidavi. Resources: M. Gholami and A. Seidavi. Supervision: M.

Chamani and A. Seidavi. Validation: M. Gholami, M. Chamani, A. Seidavi, A.A. Sadeghi and M. Aminafschar. Writing-review & editing: M. Gholami, M. Chamani, A. Seidavi, A.A. Sadeghi and M. Aminafschar.

Acknowledgments

This manuscript was prepared based on PhD thesis of first author in the Science and Research Branch, Islamic Azad University, Tehran, Iran. We are grateful to the Science and Research Branch, Islamic Azad University, Tehran, Iran for supports.

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