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Research Article
Effects of Strains and Temperature on Production Performance, Egg Qualities and Physiological Response of Laying Hens

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Abstract

Background and Objective: Bangladesh imports parent and grandparent chick from abroad to meet its internal demand of day old commercial chick. The development of layer strain considering the existing environment is a long desire in the country. Therefore, the present experiment was undertaken to compare the performance, egg quality, blood properties and stress responses between the Bangladesh Livestock Research Institute (BLRI) developed layer strains and commercial layer strain under thermo-neutral and cyclic heat stress condition of Bangladesh. **Methodology:** A total of 720 ready to lay pullets were randomly assigned to a 3×2 factorial arrangement of treatments (6 replicate/treatment, 20 birds/replication) consisting of three layer strain (Shuvra, Shorna and Hyline white commercial layer strain) and two ambient temperatures (cyclic heat stress 25-35°C, thermo-neutral 20-21°C). Data were analyzed by two way ANOVA procedures of SAS and differences were determined by Duncan multiple range test (DMRT). **Results:** Results showed that body weight was significantly ($p<0.05$) increased in Shorna than that of Shuvra and commercial hens. The interaction between strain and temperature were not significantly influence the rate of egg production. The effect of strain on egg weight was significant ($p<0.01$) and thus increased egg mass production by the Shorna than that of commercial strain. A higher number of follicles were found in the Shorna strain than that of other two strains ($p<0.05$). When temperature changed from 21-35°C, ovarian follicle number was significantly reduced ($p<0.05$). Bird's warm carcass weight and muscular pH were obtained higher in Shorna than that of Shuvra and commercial strain. But pH level of breast muscle was notably declined in heat stressed bird than that of thermo-neutral groups. **Conclusion:** Thus, the present results indicated that Shuvra and Shorna are comparable with the commercial strain, suggesting physiologically adaptable under existing environmental condition of Bangladesh.

Key words: Production performance, blood properties, ovarian follicles, layer strain, egg qualities

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Bangladesh is one of the densely populated countries in the world. During the last three decades, poultry farming in Bangladesh has transformed itself from backyard venture to a dynamic agro industry. But, the deficiency of eggs and meat is evident. Therefore, Bangladesh imports parent and grandparent chick from abroad to meet its internal demand of day old commercial chick[1]. The majority of the world's leading poultry breeding companies are located in temperate region, while their developed chicken breeds/strains are marketed all over the world in varied environmental condition which may not adapt in tropical environments resulted in large economic losses due to genotype and environment interactions[2]. Therefore, the development of layer strain considering the existing environment is a long desire in the country. Thus, the identification and development of suitable genotypes having superior performance in cyclic warm environments is of extreme challenge for the researcher in Bangladesh. In this perspective, Bangladesh Livestock Research Institute (BLRI) has developed two layer strains named as Shuvra and Shorna with the technical support of Japan International Cooperation Agency (JICA) which showed superior performance in existing tropical environment in Bangladesh[3].

The Japan International Cooperative Agency Project (JICA) is led by the Bangladesh Livestock Research Institute and funded by Japan International Cooperative Agency (JICA). Twenty years of research led to the development of layer strain noted for persistent egg production, high feed conversion efficiency and larger in egg size. Two layer strains Shorna and Shuvra developed from a series of crosses between two specialized lines and were tested in on station and in on farm condition at six geographical location of the country. Firstly, BLRI has developed Shuvra which is a white strain having higher egg production with white feather. Egg color is creamy white and day old chicks were sexed by vent sexing technique. Consequent of the research program, BLRI has developed Shorna which is brown layer strain considering the climatic condition of Bangladesh. Day old chicks were sexed by feather color. Male chicks have whitish feather whereas female have brown feather color. This layer strain starts laying brown color eggs at around 19 weeks of age and continues up to further 80 weeks[3].

High environmental temperature has been identified as a major non-genetic constraint limiting expression of their full genetic potential specially summer month in Bangladesh where environmental temperature increased to 38°C with high humidity. Several authors mentioned that birds reared under heat stress condition has been associated with decreases egg production[4,5], egg weight[6,7], egg quality[8], shell quality[9], protein digestion[4], feed digestibility and body weight[10] of laying hen. In previous, Tumova and Gous[11] mentioned that environmental temperature increased from 20-28°C does not negatively influence egg production of laying hens. Yoshida *et al.*[5] suggested that high environmental temperature negatively influences both the lipoprotein and steroid hormones of laying hens. El-Tarabany[12] mentioned that high environmental temperatures had the lowest lymphocyte percentage and highest H/L ratio and thus reduced antibody production[13]. But it depends on breed/stain of bird[14], length and intensity of the heat exposure[15]. Therefore, most of the research on the effects of different strain and temperature on the performance and physiology of laying hens has been investigated in other countries but in this aspect there is a scarcity of literature and more specifically on BLRI developed layer strain in Bangladesh. Thus, the present study was aimed to investigate the effect of the strain × ambient temperature interaction on the performance, egg quality and physiological responses of laying hens.

MATERIALS AND METHODS

Study site: This experiment was conducted at Poultry Production Research Farm, Bangladesh Livestock Research Institute for a period of 64 weeks from October, 2014 to December, 2015.

Birds and management: At 12 weeks of age, a total of 240 Hyline white pullets were purchased from a commercial farm and Bangladesh Livestock Research Institute (BLRI) developed layer strains (240 from each strain) were selected from existing flock to conduct this experiment. During start of the trial, the average body weight of Shuvra, Shorna and commercial Hyline white strain were 955, 973 and 960 g, respectively. Therefore, a total of 720 ready to lay pullets were weighted and equalized body weight of each strain and were assigned to a 3×2 factorial arrangement of treatments (6 replicates/treatment, 20 birds/replication) consisting of three layer strain (Shuvra, Shorna and commercial Hyline white layer strain) and two temperatures (thermo-neutral and cyclic heat stress) condition. In the thermo-neutral room, the control temperature of 20-21°C was maintained throughout the experiment. In cyclic heat stress condition, temperature during the hot period was 35-38°C with 39-81% relative humidity and 25-26°C temperature with 47-91% relative

humidity during the cool period. Ambient temperature and relative humidity were measured at 4 h interval using a Tinytalk™ II Data Logger device. Birds were reared in conventional individual layer cages with a dimension of 864 cm^2 per hen (24 cm width × 36 cm length) until the end of the experimental period of 72 weeks. Replicates were equally distributed between upper and lower tiers to minimize cage-level effect. A total of 120 g of feed/bird (ME, 2800 kcal kg^{-1}, CP 17%, Ca 3.5% and P 0.42%) was provided twice in a day at 08.00 AM and 3.30 PM and refusals were recorded following morning. Drinking water was available all the time. At 12 weeks, light was provided 12 h, followed by increments of light 30 min in each week to reach 16 h at the bird's age of 20 weeks. Mortality was recorded as it occurred and eggs were collected daily in the afternoon. During the trial, hens were kept under standard management condition without addition of feed additives in the diet. Vaccination was practiced according to the schedule. To protect infectious bronchitis and Newcastle disease of the bird, Ma5+ Clone 30 vaccine was provided in each 40-45 days interval. All management of hens and experimental procedures were conducted in accordance with the Institutional Animal Care and Use Committee at Bangladesh Livestock Research Institute, Savar, Dhaka.

Measurement of performance: Egg production (EP) and feed intake (FI) in each treatment were recorded daily and body weight (BW) and egg weight (EW) were weighed 1 day in a week. Hen/day egg production was recorded from 20-72 weeks of age. During this period, random samples of 30 eggs/treatment were collected per week (5 eggs/replicate). Therefore, a total of 1560 eggs were weighed in each treatment to determine average egg weight throughout the trial. The feed intake and feed conversion ratio (FCR) were determined weekly. The FCR was determined as gram of feed consumed per gram of egg produced (g of feed g^{-1} of egg). Egg mass was calculated by multiplying egg weight by egg production rate. Hen mortality was recorded as it occurred and feed intake and egg production were adjusted.

Egg quality measurement: In each 5 weeks interval, 10 eggs (60 eggs/treatment) were randomly picked up per replicate cage to assess egg quality parameters. Therefore, in each treatment 840 eggs in total which were collected 11 times with 4 weeks intervals were analyzed for egg quality. Egg shell breaking strength was measured by using an egg shell strength tester (Fujihira Industry Co., Ltd, Japan) and expressed as unit of compression force exposed to unit egg shell surface area (kg cm^{-2}). Then, eggs were singularly weighed and carefully broken on a glass plate and albumen height and width, yolk height and width were measured by Egg Quality Measurement Stand (FHK Japan). Yolk color was measured by Minolta Chroma Meter CR-200. Haugh unit (HU) was calculated as:

$$\text{Haugh unit (\%)} = 100 \times \log (H + 7.57 - 1.7W^{0.37})$$

Where:
H = Height of the albumen in mm
W = Weight of the egg

Measurement of blood properties: At the end of the experiment, a total of 60 birds (10 birds from each treatment, 20 in each strain) were randomly selected and peripheral blood samples were obtained by wing vein puncture and allowed to clot for 2 h at room temperature, centrifuged at 1500 rpm for 15 min at 4°C and the sera were collected and stored at -20°C until analyses. Serum triglycerides (TG), total cholesterol (TCL), high density lipoprotein (HDL), Ca, P and Mg (mg mL^{-1}) content were measured by using a Humalyzer 2000 chemistry (Germany) using a turbidimetric method as described by the manufacturer. To measure the stress response, 10 blood samples/treatment were collected from the wing vein, smears were prepared and lymphocytes were counted at ×100 (oil immersion lens) and H/L was calculated according to Wall *et al.*[16]. Hemagglutination inhibition (HI) antibody titers of the sera samples were measured based on the Sabrin *et al.*[17].

Meat quality measurement: At the end of the experiment, live weight of 10 birds/treatment were measured, euthanized by cervical dislocation, dressed and eviscerated. Viscera were removed and the ready to cook carcass weight was determined and the carcass yield percentage was calculated by dividing the ready to cook carcass weight by the live BW of birds multiplied by 100. The liver, breast and thigh muscle were excised and weighed. The pH of breast muscle samples was determined by homogenizing 5 g of sample with 50 mL distilled water for 1 min in Ultra Turrex T25 tissue homogenizer (Janke and Kenkel, IKA Labor Technik, Germany). The pH of the suspension was recorded by dipping the combined glass electrode of digital pH meter (Elico, India, Model LI 114). To measure drip loss of the raw meat, the pectoralis major muscle was weighed and immediately placed in a plastic bag, hung from a hook and stored at 2°C for 4 days. After hanging, the sample was wiped with absorbent paper and weighed again. The difference in weight corresponded to the drip loss and was expressed as the percentage of the initial muscle weight.

Ovarian morphology measurements: At the end of the experiment, 10 birds/strain and treatment were selected randomly and killed humanly and ovary and stromal weights were recorded. Deepest care was performed in handling, to avoid ovarian damage caused by excessive post-mortem movement. The weight (g) parameters measured included the ovary, total large yellow follicles (TLYFW) and stroma weight. The numbers of follicles were recorded, counted and sorted by size. The remainder of the ovary was briefly rinsed in saline solution (9 g L^{-1} NaCl) and placed in 10% buffered formalin. The healthy follicles were sized after the yolk had hardened (2-3 days fixation) and diameter were measured according to Hassan *et al.*[18].

Statistical analysis: The strain and temperature data were analyzed as a completely randomized design (CRD) using a factorial 3×2 arrangement, with strain (Shuvra, Shorna and Hyline commercial white strain) as first factor and temperature (thermo-neutral and cyclic heat stress) as the other. The method applied for this repeated measures analysis was based on the mixed model (PROC MIXED, SAS Institute, Cary, NC, USA)[19] and data were fitted to a model that included the effects of strain, temperature and strain× temperature. For BW, EP, EW, EM, FI and FCR the cage tier (n = 4) were the experimental units. For other parameters (n = 10) birds were considered as the experimental unit. Significant differences among treatment means were separated using the Duncan's new multiple-range test[20]. A $p<0.05$ was considered significant.

RESULTS

Laying performance: The performance of laying hens during the entire trial period (20-72 weeks) was summarized in Table 1. The interaction between strain and temperature were not significantly influenced the rate of egg production, egg weight and FCR except egg mass production. Though the egg production was not significantly influenced by the interaction of strain and temperature but numerically higher egg production rate was found in commercial strain. On the other hand, egg weight was significantly higher ($p<0.01$) in Shorna compared to other two strains. Therefore, the interaction of strain and temperature significantly increased egg mass production of Shorna. In both temperature condition, body weight was significantly ($p<0.05$) higher in Shorna than that of other two strains. When environmental temperature increased from thermo-neutral to cyclic heat stress condition, feed intake was decreased significantly ($p<0.05$). Though the interaction of strain and temperature was not influenced the FCR but Shorna improved.

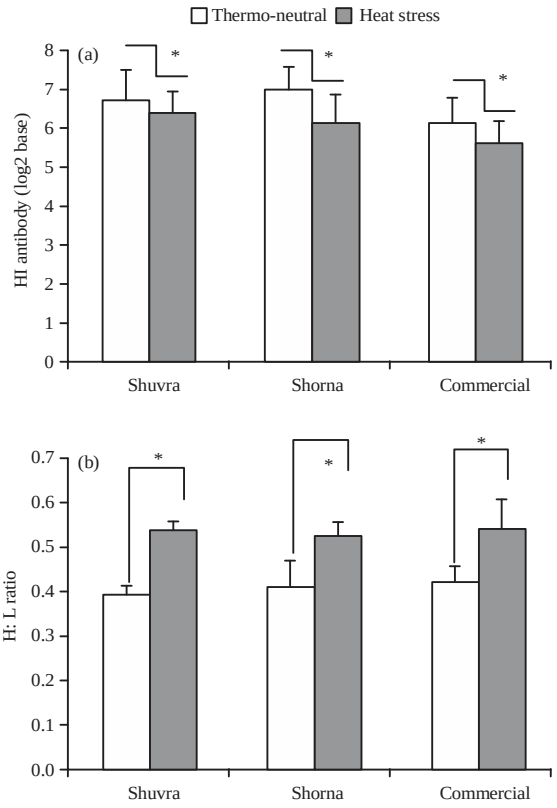

Fig. 1(a-b): Effect of strain and temperature on (a) Antibody titer of laying hens and (b) H: L of laying hens
*: $p<0.05$ thermo-neutral vs heat stress

Egg quality: There was no significant interaction between strain and temperature on albumen height, albumen width, albumen index, yolk height, yolk width, yolk index and Haugh units (Table 2). But, egg shell breaking strength (ESBS), yolk color and yolk height was influenced significantly by the interaction of strain and temperature. On the other hand, Shuvra showed significantly higher ($p<0.05$) egg shell breaking strength (ESBS), Haugh unit (HU), albumen index and yolk height than that of other two strains. Under the cyclic heat stress condition, albumen height, albumen index, yolk height, yolk index and Haugh unit of egg was significantly ($p<0.05$) decreased than that of thermo-neutral condition.

Blood properties: Though the H: L ratio was not significantly affected ($p>0.05$) by the interaction of strain×temperature (Fig. 1b). In the present results, strain did not influence the H:L ratio of laying hen. But, environmental temperature increased from 21-35°C might be influenced and thus increased ($p<0.05$) H: L ratio from 0.406-0.532. On the other hand, HI antibody titer in serum was not influenced by the interaction of strain and temperature level (Fig. 1a) but numerically higher

Table 1: Effect of strain and temperature on the performance of laying hens

Layer strains (S)	Temperature (T)	BW (g)	EP rate (%)	EW (g)	EM (g/day)	FI (g/bird/day)	Egg mass production (kg)	FCR (g of feed g^{-1} of egg)
Shuvra	Thermo-neutral	1612.90^{b}	79.07	62.27	49.23^{c}	112.16^{a}	17.96^{ab}	2.278
	Cyclic heat stress	1585.78^{b}	78.21	61.94	48.44^{bc}	107.39^{b}	17.68^{b}	2.217
Shorna	Thermo-neutral	1910.61^{a}	80.17	65.54	52.54^{a}	116.71^{a}	19.18^{a}	2.231
	Cyclic heat stress	1882.67^{a}	78.69	65.07	51.20^{a}	109.75^{ab}	18.69^{ab}	2.145
Commercial strain	Thermo-neutral	1481.15^{c}	84.46	60.36	50.98^{a}	113.06^{a}	18.61^{ab}	2.218
	Cyclic heat stress	1463.29^{c}	80.47	60.35	48.57^{c}	106.96^{b}	17.72^{b}	2.203
SEM		39.99	0.612	0.491	0.487	0.694	0.157	0.027
Main effects								
Layer strains	Shuvra	1599.34^{b}	78.64^{b}	62.11^{b}	48.84^{b}	109.78^{b}	17.83^{b}	2.249^{a}
	Shorna	1896.64^{a}	79.43^{ab}	65.30^{a}	51.87^{a}	113.23^{a}	18.93^{a}	2.195^{b}
	Commercial	1472.22^{c}	82.47^{a}	60.36^{c}	49.78^{b}	110.01^{b}	18.17^{ab}	2.211^{ab}
Temperature	Thermo-neutral	1701.55^{a}	81.23^{a}	62.73	50.95	113.97^{a}	18.59	2.232
	Cyclic heat stress	1610.59^{b}	79.12^{b}	62.45	49.62	108.08^{b}	18.03	2.194
Treatment interaction effect (p>F) p-value								
S		0.001	0.020	0.001	0.005	0.014	0.037	0.031
T		0.001	0.039	0.213	0.194	0.039	0.148	0.491
S×T		0.013	0.326	0.508	0.043	0.042	0.029	0.058

SEM: Standard error of mean, ^{a,b,c}Mean values within a column followed by the same letter are not significantly different (p>0.05), BW: Body weight, EP: Egg production, EW: Egg weight, EM: Egg mass, FI: Feed intake, FCR: Feed conversion ratio, cyclic heat stress: 25-35°C, thermo-neutral: 20-21°C, S: Strain, T: Temperature, S×T: Strain×temperature

Table 2: Effect of strain and temperature on egg qualities of laying hens collected at 5 weeks interval

Layer strain (S)	Ambient temperature (T)	AH (mm)	AW (mm)	AI (%)	YC	YH (mm)	YW (mm)	YI (%)	HU	ESBS (kg cm^{-2})
Shuvra	Thermo-neutral	9.58	72.03	13.30	6.80^{a}	21.06^{a}	40.42	50.79	97.22	4.36^{a}
	Cyclic heat stress	8.54	75.45	11.40	5.71^{a}	18.00^{ab}	41.41	43.54	91.76	3.84^{ab}
Shorna	Thermo-neutral	8.81	79.63	9.77	6.58^{a}	19.02^{ab}	41.03	45.91	86.19	3.58^{ab}
	Cyclic heat stress	8.07	81.26	8.78	6.31^{ab}	17.27^{b}	40.07	43.21	81.87	2.93^{b}
Commercial strain	Thermo-neutral	9.25	74.15	12.56	6.36^{ab}	19.12^{ab}	40.19	47.58	95.22	4.03^{a}
	Cyclic heat stress	8.41	72.48	11.67	5.61^{b}	17.69^{b}	40.21	44.00	91.22	3.63^{ab}
SEM		0.185	0.97	0.335	0.081	0.207	0.216	0.523	1.094	0.121
Main effects										
Layer strain	Shuvra	8.97	74.04^{b}	12.35^{a}	6.26^{a}	19.53a	41.01	45.78	94.01^{a}	4.10^{a}
	Shorna	8.41	80.61^{a}	9.28^{b}	6.45^{a}	18.15^{b}	40.43	44.11	83.89^{b}	3.26^{b}
	Commercial	8.78	73.21^{b}	12.12^{a}	5.98^{b}	18.41^{b}	40.21	45.47	92.97^{a}	3.83^{a}
Temperature	Thermo-neutral	8.89^{a}	75.05	11.88^{a}	6.58^{a}	19.73^{a}	40.53	47.86^{a}	92.88^{a}	3.99
	Cyclic heat stress	8.06^{b}	76.36	10.62^{b}	5.87^{b}	17.64^{b}	40.59	43.58^{b}	88.65^{b}	3.47
Treatment interaction effect (p>F) p-value										
S		0.214	0.004	0.001	0.008	0.003	0.426	0.078	0.001	0.014
T		0.007	0.533	0.024	0.001	0.001	0.968	0.0001	0.011	0.079
S×T		0.919	0.495	0.697	0.024	0.036	0.216	0.113	0.935	0.018

SEM: Standard error of mean, ^{a,b,c}Mean values within a column followed by the same letter are not significantly different (p>0.05), AH: Albumen height, AW: Albumen width, AI: Albumen index, YC: Yolk color, YH: Yolk height, YW: Yolk width, YI: Yolk index, HU: Haugh unit, ESBS: Egg shell breaking strength, cyclic heat stress: 25-35°C, thermo-neutral: 20-21°C, S: Strain, T: Temperature, S×T: Strain×temperature

Table 3: Effect of strain and temperature on blood properties of laying hens

Layer strain (S)	Ambient temperature (T)	TG (mg dL^{-1})	TCL (mg dL^{-1})	HDL (mg dL^{-1})	Ca (mg dL^{-1})	P (mg dL^{-1})	Mg (mg dL^{-1})
Shuvra	Thermo-neutral	1114.70	113.60	37.8	12.39	11.14	2.90
	Cyclic heat stress	1204.70	115.90	37.9	10.97	7.54	3.12
Shorna	Thermo-neutral	850.40	93.90	37.4	13.14	12.30	2.15
	Cyclic heat stress	1010.40	101.00	37.2	10.34	10.40	1.99
Commercial strain	Thermo-neutral	855.30	98.40	35.3	12.94	8.24	2.59
	Cyclic heat stress	1245.40	121.30	36.8	9.70	5.26	2.61
SEM		221.38	32.10	5.45	0.221	0.701	0.188
Main effects							
Layer strain	Shuvra	1159.70	114.75	37.85	11.68	9.34^{ab}	3.01
	Shorna	930.40	97.45	37.30	11.74	11.35^{a}	2.07
	Commercial	1050.35	109.85	36.05	11.32	6.75^{b}	2.60
Temperature	Thermo-neutral	940.13	101.97	36.83	12.82	10.56^{a}	2.54
	Cyclic heat stress	1153.50	112.73	37.33	10.33	7.73^{b}	2.57
Treatment interaction effect (p>F) p-value							
S		0.215	0.329	0.871	0.734	0.017	0.127
T		0.316	0.467	0.765	0.094	0.034	0.321
S×T		0.644	0.473	0.893	0.541	0.054	0.726

^{a,b}Mean values within a column followed by the same letter are not significantly different (p>0.05), Values are mean±SE. TCL: Total cholesterol, TG: Triglyceride, HDL: High density lipoprotein, Ca: Calcium, P: Phosphorus, Mg: Magnesium, cyclic heat stress: 25-35°C, thermo-neutral: 20-21°C, S: Strain, T: Temperature, S×T: Strain×temperature

level was obtained (log2 base) by the Shorna and Shuvra than that of commercial strain. But, hemagglutination inhibition (HI) antibody titre level was decreased with increasing environmental temperature.

Consequently, variation of strain and temperature did influence the blood P contents of laying hens and numerically higher Ca content in serum was obtained by the Shorna and Shuvra than that of commercial strain (Table 3). There were no strain and temperature interactions regarding triglycerides (TG), total cholesterol (TCL) and high density lipoprotein (HDL) concentrations of blood plasma (Table 3). With increasing environmental temperature from thermo neutral condition to cyclic heat stress condition plasma TG and TCL level was increased but did not reach to the significant level.

Meat qualities: The present results showed that there was no interaction between strain and temperature on meat quality characteristics (Table 4) except live weight and muscular pH. In both temperature condition, significantly higher ($p<0.05$) live weight was attained in Shorna than that of Shuvra and commercial layer strain. On the other hand, muscular pH was also significantly influenced by the interaction of strain and temperature. Under thermo-neutral condition, higher muscular pH was found from Shorna than the interaction of commercial strain under cyclic heat stress condition. The drip loss (%) in breast muscles was not significantly influenced by the interaction of strain and temperature. But pH level of breast muscle was notably declined in cyclic heat stressed bird than that of thermo-neutral groups.

Ovarian morphology: The interaction of strain and temperature were not significantly influenced ovarian follicle numbers of laying hens (Table 5). But, a higher number of follicles (1-3 mm, 3-4 mm and 10 to above mm sized follicles) were found in Shorna than that of Shuvra and commercial strains of hen. On the other hand, follicle numbers (1-3, 3-4 and 4-6 mm) were decreased when environmental temperature was increased from thermo-neutral to cyclic heat stress condition of laying hens. In contrast, ovary weight, stromal weight and total large follicle weight were not significantly affected by the interaction of strain and temperature.

DISCUSSION

The present results showed that the effect of interaction of strain×temperature was not significant, on egg production. Though the egg production of commercial hen was increased

Table 4: Effect of strain and temperature on meat quality of laying hens at 72 weeks of age

Layer strain (S)	Ambient temperature (T)	Live weight (g)	Warm carcass weight (g)	Dressing (%)	Breast muscle (%)	Thigh muscle (%)	Drip loss (%)	pH	Liver wt. (%)
Shuvra	Thermo-neutral	1653.67[b]	1319.28	79.78	8.66	5.27	15.87	5.89[a]	1.871
	Cyclic heat stress	1607.71[b]	1269.31	78.94	8.59	4.75	17.24	5.68[b]	1.876
Shorna	Thermo-neutral	2092.73[a]	1642.58	78.49	8.33	5.12	18.89	5.91[a]	1.567
	Cyclic heat stress	2051.49[a]	1624.17	79.17	7.78	4.69	19.58	5.79[ab]	1.637
Commercial strain	Thermo-neutral	1550.20[c]	1238.14	79.87	9.07	5.57	15.48	5.81[ab]	2.053
	Cyclic heat stress	1549.63[c]	1223.43	78.95	8.97	5.15	16.19	5.60[b]	1.942
SEM		39.99	43.88	0.276	0.061	0.051	0.598	0.022	0.011
Main effects									
Layer strain	Shuvra	1630.69[b]	1294.29[b]	79.36	8.63	5.02	16.56	5.78[ab]	1.872
	Shorna	2072.11[a]	1633.38[a]	78.83	8.06	4.91	19.23	5.85[a]	1.602
	Commercial	1549.92[b]	1230.79[b]	79.41	9.02	5.36	15.84	5.71[b]	1.997
Temperature	Thermo-neutral	1765.52	1399.89	79.38	8.65	5.30	16.75	5.88[a]	1.802
	Cyclic heat stress	1736.28	1372.30	79.02	8.39	4.85	17.67	5.69[b]	1.790
Treatment interaction effect (p>F) p-value									
S		0.0001	0.0001	0.261	0.085	0.127	0.261	0.011	0.174
T		0.074	0.087	0.489	0.089	0.098	0.354	0.021	0.248
S×T		0.024	0.237	0.873	0.375	0.451	0.871	0.035	0.782

SEM: Standard error of mean, [a,b,c]Mean values within a column followed by the same letter are not significantly different (p>0.05), cyclic heat stress: 25-35°C, thermo-neutral: 20-21°C, S: Strain, T: Temperature, S×T: Strain×temperature

Table 5: Effect of strain and temperature on ovarian morphology of laying hens

Layer strain (S)	Ambient temperature (T)	Ovary weight (g)	TLYFW (g)	Stroma weight (g)	Follicle number					
					1-3 mm	3-4 mm	4-6 mm	6-7 mm	7-9 mm	10 mm to above
Shuvra	Thermo-neutral	49.25	38.41	6.21	26.39	8.27	11.47	3.89	4.39	6.41
	Cyclic heat stress	45.98	31.07	3.97	17.87	5.75	8.29	3.25	2.74	3.63
Shorna	Thermo-neutral	53.21	46.29	5.98	37.14	12.62	9.37	4.67	3.12	7.15
	Cyclic heat stress	49.69	40.31	5.67	33.60	10.38	6.65	3.39	2.14	5.61
Commercial strain	Thermo-neutral	52.19	38.59	5.49	34.18	7.43	7.39	4.56	2.98	6.25
	Cyclic heat stress	43.18	36.63	5.63	31.32	4.07	4.87	2.58	2.74	4.75
SEM		1.462	1.909	0.329	2.33	0.814	0.794	0.406	0.329	0.188
Main effect										
Layer strain	Shuvra	47.62	34.74	5.09	22.13[b]	7.01[b]	9.88	3.57	3.57	5.02[b]
	Shorna	51.45	43.30	5.83	35.37[a]	11.50[a]	8.01	4.03	2.63	6.38[a]
	Commercial	47.18	37.61	5.56	32.75[a]	5.75[b]	6.13	3.57	2.86	5.50[ab]
Temperature	Thermo-neutral	51.55	41.09	5.89	32.57[a]	9.44[a]	9.41[a]	4.37	3.50	6.60
	Cyclic heat stress	46.29	36.01	5.09	27.60[b]	6.73[b]	6.60[b]	3.07	2.54	4.66
Treatment interaction effect (p>F) p-value										
S		0.434	0.179	0.671	0.041	0.005	0.157	0.889	0.496	0.005
T		0.359	0.289	0.735	0.015	0.037	0.045	0.321	0.148	0.168
S×T		0.347	0.871	0.897	0.089	0.094	0.432	0.578	0.398	0.379

SEM: Standard error of mean, [a,b,c]Mean values within a column followed by the same letter are not significantly different (p>0.05), TLYFW: Total large yellow follicle weight, cyclic heat stress: 25-35°C, thermo-neutral: 20-21°C, S: Strain, T: Temperature, S×T: Strain×temperature

under thermo-neutral condition but numerically decreased under the cyclic heat stress condition. Therefore, egg production was dropped 4% in commercial hen, 2 % in Shorna and 1% in Shuvra due to heat stress condition. These results also agreed with those of Panda *et al.*[21] and Kirunda *et al.*[22], who reported that egg production in layer hens decreased when they were exposed to high environmental temperature. It might be due to the decrease in feed consumption and thus reduce the available nutrients for egg production. Therefore, Bonnet *et al.*[10] mentioned that heat stress not only reduces feed intake but also reduce digestibility of the diet and amino acids[23] and thus reduces plasma protein concentration[24]. In previous, Sandercock[25] noted that degree of hyperthermia may differ due to variations in thermo-tolerance ability of the strain and which agrees with the present findings. Moreover, the heat-induced egg mass reduction was significantly higher for commercial strain than the Shorna and Shuvra strain which may suggest poor thermo-tolerance ability of the commercial line. It has been reported that birds with lighter body weight have a greater tolerance to high temperatures than heavier body weight[25-28]. The feed intake reduction in response to heat stress is in agreement with earlier findings[15,21-22,29]. The reduced feed consumption and subsequent undersupply of needed nutrients quickly affect the productivity of the flock[30].

Exposure of hens to high temperatures resulted in a significant decrease in albumen height, yolk width, yolk index and Haugh unit. These results were in agreement with the results of Rama and Nagalakshmi[31]. The decrease in egg weight due to heat stress was in line with those of Lara and Rostagno[7] and Kirunda *et al.*[22]. They compared 21°C with either 29, 31 or 35°C and found a considerable depression in egg weight in various chicken breeds due to reduced feed consumption.

In the present trial, though the albumen width was increased but Haugh unit and egg shell breaking strength were reduced by the shorna strain than that of other two strains might be due to lay 5 g lager eggs and therefore, need more labile reservoir of calcium in their medullary bone. When birds were exposed to thermo-neutral condition to cyclic heat stress, eggshell breaking strength was reduced numerically but the effect was non-significant. It might be due to reduce calcium intake as a direct consequence of reduced feed intake and this stimulates bone resorption resulting in hyperphosphatemia, which inhibits the formation of calcium carbonate in the shell gland of laying hens[32]. Mahmoud *et al.*[33] reported that plasma calcium level was significantly decreased in laying hens when the birds were exposed to high temperatures.

Though the current results showed that the interaction of strain and temperature were not significantly influenced H:L ratio and HI antibody title level. But, birds from the cyclic heat-stressed group had significantly increase H: L ratio and lower antibody titers to ND and than those from the thermo-neutral group might be due to reduce antibody synthesis and which agrees with the findings of Zulkifli *et al.*[13]. In another experiment, Ogle *et al.*[32] mentioned that an increase in inflammatory cytokines under heat stress, which stimulates the hypothalamic production of corticotrophin releasing factor[34] which is known to increase adrenocorticotropic hormone from the pituitary and thus stimulates corticosterone production from the adrenal gland. This corticosterone finally inhibits antibody production[35]. Therefore, the present results could indicate that exposure to heat stress can increase both the H:L ratio and decrease the antibody titre level.

The pH is one of the important parameters for quality profiling of meat. In the present results, Shorna strain increased warm carcass weight and meat pH indicating better meat quality that was characterized by lower protein damage which agrees with the findings of Hassan *et al.*[36]. In this study, no effects of strain and temperature on drip loss of breast muscle. In the present experiment, author did not measure shear force but was found higher pH in shorna strain suggesting that this meat is more acceptable to the consumer[37] than those of commercial spent hen meat.

The interaction of strain and temperature significantly influenced ovarian follicle number (1-3 and 4-6 mm in size) and these small yellow follicles and large white follicles (LWFs) provide a constant supply of growing follicles for the hierarchy[38] and these developed follicles form yellow-yolky follicles in the ovary and finally influence lay rate. Due to lack of previous study regarding this strain under different temperature condition, a direct comparison was not possible with the present results.

CONCLUSION

These results indicated that Shuvra and Shorna increased yolk color, serum phosphorus, antibody titer level and numerically decreased H:L ratio with increased egg mass production as evidenced by measured performance and physiological parameters. It also clears that cyclic heat stress of the hen caused poor production performance and decrease HI antibody titre. Thus, the present results indicated that Shuvra and Shorna are comparable with the commercial strain, suggesting physiologically adaptable under existing cyclic environmental condition of Bangladesh.

SIGNIFICANCE STATEMENT

This study discovers that BLRI developed layer strain is comparable with the commercial strain without negative effect on the performance, egg qualities or physiological responses under thermo-neutral or heat stress condition. The present results will help to establish guidelines for temperature control in laying hen houses in Bangladesh, especially during the summer months when birds are most susceptible to heat stress. Therefore, farmer's may be replaced commercial strain with Shuvra and or Shorna and reared under existing cyclic environmental condition of Bangladesh.

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