

## Seasonal Behaviour Adaptation of Broilers with Anatomical Interpretation during Summer Heat Stress

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### Abstract

This study was conducted to show the seasonal behavioral changes with some anatomical interpretation to the heat-exchange system. The study applied on 200 one day old broiler chicks, 100 reared in winter season (winter group), and 100 reared in summer (summer group), each group two replicates, 50 for each. The rearing period was 35 days. Chicken behaviour was recorded by visual observation at daily scan sampling 3 times /day, 10 minutes / for each replicate. The following behavioral patterns were recorded, feeding, drinking, leg and wing stretching, body scratching, preening and resting. Final body weight, total feed intake, food conversion ratio and mortality rates were measured as performance index. The arterial blood supply and venous drainage of the pelvic limbs of the chicken were demonstrated by injection of colored gum milk latex and treated by the ordinary method of preservation. Arterio-venous association was investigated in the tibial region of 10 birds in each group. The study revealed that the behaviour parameters in summer and winter are greatly significantly differed at  $P \leq 0.05$ , summer group showed higher percentage of resting behaviour  $33 \pm 0.94$  %, and higher percentage of leg and wing stretch compared with winter group. Final body weight, feed intake, were significantly differed at  $P \leq 0.05$ , winter group showed the highest final body weight  $2093 \pm 0.75$  gm and in the same time lower feed intake  $3532 \pm 10.5$  gm compared with summer group. Increasing of resting behaviour and leg & wing stretch in broiler chicken reared in summer was explained on the basis of bird anatomy. The intermingled network of arteries and veins (rete tibiotarsale) help in thermoregulatory mechanism because exchange of heat between arteries and veins is considered to be of a great importance to keep the bird body temperature within the normal.

**Key words:** Broiler, Heat stress, Behaviour, Artery, Vein.

### Introduction

Stress occurred when an animal experiences change in the environment that stimulates body responses aimed at re-establishing homeostatic conditions. Environmental stress includes abiotic factors (climate, and temperature) and biotic factors (various forms of infectious diseases) Mumma et al., (2006).

The importance of animal response to environmental challenges applied to all species. However, poultry seemed to be particularly sensitive to temperature environmental changes, especially heat stress. Settar et al., (1999) and Deeb and Canhar (2002).

Under high temperature condition, birds alter their behavior seeking thermoregulation, when birds subjected to heat stress conditions spend less time feeding,

more time drinking and panting, as well as more time with their wings stretch, less time moving or walking, and more time resting Mack et al., (2013).

Animals utilized multiple ways for maintaining thermoregulation and homeostasis when subjected to high environmental temperatures, including increasing radiant, convective and evaporative heat loss by vasodilatation Mustafet al., (2009).

Arteriovenous anastomosis (AVAs) is important in local and general temperature regulation. There is very little information about the role of anatomy of the vascular system on the heat loss. Bogin et al., (1996 a, b). So the aim of the present study was to follow the behavioral changes of broiler chicken in summer and winter with some anatomical interpretation to the mechanism of heat loss.

## Materials and Methods

### *Birds and Housing:*

A total of 200 broiler cobb chicks, were used in this study, housed in experimental unit at Faculty of Veterinary Medicine, Cairo University, Egypt, with stocking density 10/ m<sup>2</sup>, using 4 pens, 50 chicks for each. Feed and water were provided ad libitum via trough feeders and bell drinker.

The birds were vaccinated against Newcastle disease and Infectious bronchitis and Gumboro. All diets used were in pellets form and formulated to meet the nutrient requirement of the broiler chicks (Table 1), according to recommendations of the national research council. NRC (1994)

**Table 1:** Composition and nutritive value of starter, grower and finisher diet used.

Ingredients	Starter	Grower	Finisher
Yellow corn	61.4	68.3	73.4
Soya bean meal (46%)	29.9	20.3	15.5
Full fat soy (35%)	1	1	3.2
Corn gluten meal (62%)	3.5	6.1	3.7
DL-Methionine	0.26	0.27	0.3
L-Lysine HCL	0.265	0.450	0.470
L-Threonine	0.085	0.085	0.3
Mono calcium phosphate	1.17	1.13	0.75
Lime stone	1.63	1.575	1.5
Salt	0.24	0.24	0.23
Sodium bicarbonate	0.2	0.2	0.3
Choline chloride (60 %)	0.05	0.05	0.05
Premix	0.3	0.3	0.3
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>
<b>Calculated chemical composition (%)</b>			



Crude protein (%)	21.6	19.5	17.07
Metabolisable energy (Kcal/kg)	3050	3150	3200
Calcium (%)	0.1	0.95	0.9
Phosphorus (total) (%)	0.64	0.6	0.57
Available phosphorus (%)	0.5	0.48	0.46
Methionine %	0.63	0.63	0.61
Lysine %	1.3	1.21	1.12
Threonine %	0.95	0.85	0.77
Sodium %	0.17	0.17	0.17

#### **Experimental design:**

200 Birds were divided into two groups. Winter group; 100 chicks (2 replicates), reared at ideal environmental temperature (24°C -25°C). The brooding temperature was 35°C at one day old and gradually decreased 3°C /week until reach to 24-25°C at 21 days old and then kept constant until 35 days old. Summer group, 100 chicks, (2replicates), left on the normal environmental temperature range 32°C –40°C and relative humidity range 65 % - 75 %.

#### **Measurements:**

In both groups the same measurement were taken;

#### **Behavioral measurements:**

The behavioral patterns were observed and measured throughout the rearing periods including; feeding behaviour, drinking behaviour, welfare index behaviour including leg and wing stretching, preening, leg scratch and resting behaviour. Measurement applied according to Altman (1974) through daily scan sampling, 3 times /day, 10 minutes / for each replicate; so the total scan observation period was 60 minutes for each group/day. The results were expressed as the percentage of birds performing the behaviour Reiter and Bessei, (2000).

#### **Productive index:**

Final body weight, feed intake, feed conversion ratio and mortality rate (%) were recorded.

#### **Pelvic limbs anatomy:**

Samples of 10 live large size birds at 1.7 to 2 kg of body weight were taken from each group, before exsanguinations, the birds were anaesthetized by intramuscular injection of 0.5 cm of 2% xylazine hydrochloride, (*Dutch farm veterinary pharmaceuticals*) to ensure proper relaxation and avoid vasoconstriction. Then injection of heparin (*Calheparin, 5000 I.U.*) in the wing vein diluted by 1 to 2 cm. saline solution to prevent blood clotting.

Each specimen was exsanguinated by cutting the common carotid arteries. The ventricular mass of the heart was removed and a nelaton catheter of size 8F to 10F (*Ma Medical Company*) was introduced into the left ventricle of the heart to the descending

aorta for arteries injection of the pelvic limb and it also was introduced into the right ventricle of the heart to the caudal vena cava for veins injection of the pelvic limb, El-Gammal (2012).

Different methods were used for preparation of the specimens for dissection.

- A. Injection of 60% of latex neoprene colored using red rottring ink for the arteries and blue one for the veins
- B. The specimens were kept in 10% formalin, 4% phenol and 1% glycerin before dissection.

The nomenclature used in this study was that given by the *Nomina Anatomica Avium*, according to Baumel et. al., (1993).

### Statistical Analysis:

The results were analyzed statistically using variance analysis and significant differences were estimated with Duncan's test and using Chi-square test for behavioral observations. (Ewa and Renata 2005).

## Results

### Behavioral measurements:

Regarding the results of behaviour patterns in table 2, there were statistical significance differences between two groups at  $P \leq 0.05$ , in feeding behaviour; as winter group showed higher feeding percentage  $8.75 \pm 0.32$  % than during summer  $3.67 \pm 0.22$  %, while drinking behaviour was lower during winter  $4.61 \pm 0.16$  % compared with summer group  $6.47 \pm 0.25$  %.

Table 2. Behaviour Patterns of broiler chickens in two different seasons

Group	Behaviour patterns					
	Feeding beh.	Drinking	Leg and wing stretch	Welfare Index behaviour		
				Preening	body scratching	Resting
Winter	$8.75 \pm 0.32^a$	$4.61 \pm 0.16^b$	$5.99 \pm 0.15^b$	$7.95 \pm 0.15^a$	$6.4 \pm 0.18^a$	$12.37 \pm 0.13^5$
Summer	$3.67 \pm 0.22^b$	$6.47 \pm 0.25^a$	$8.47 \pm 0.92^a$	$4.3 \pm 0.14^b$	$4.92 \pm 0.8^b$	$33 \pm 0.94^1$

- Behaviour pattern expressed as average percentage of birds showing the behaviour during observation time.
- Result equal Mean  $\pm$  stander error.
- <sup>a,b</sup> Means with the different indices between groups are significantly different at  $p < 0.05$ .



Regarding to welfare indicator behaviour parameters, there were statistical significance differences between two groups at  $P \leq 0.05$ , during summer, birds showed higher resting percentage  $33 \pm 0.94 \%$ , during summer birds showed frequent special lateral resting position with expansion to pelvic limb and wing of the opposite side of resting (Fig 1). Also the summer group showed higher percentage of leg and wing stretch  $8.47 \pm 0.92 \%$  compared with winter group  $5.99 \pm 0.15 \%$ , but preening and body scratching was lower during summer  $4.3 \pm 0.14 \%$  and  $4.92 \pm 0.8$  respectively, compared with winter group  $7.95 \pm 0.15 \%$  and  $6.4 \pm 0.18 \%$ .

**Productive index:**

Performance of broilers including final body weight, average feed intake, feed conversion ratio and mortality rate as presented in table 3; there was a highly significance difference between the productive performance parameters at  $P \leq 0.05$ . Winter group showed the highest average body weight  $2093 \pm 0.75$  gm, followed by summer group  $1740 \pm 0.93$  gm, while the average feed intake recorded was  $3975 \pm 6.5$  gm and  $3532 \pm 10.5$  gm in winter group and summer group respectively. Lower food conversion rate achieved in winter group  $1.9 \pm 0.00$ , followed by summer group  $2.03 \pm 0.07$ . Also the mortality rate showed a highly significance difference between different groups, winter group showed lower mortality rate  $3.5 \pm 0.08 \%$ , followed by summer group  $6.5 \pm 0.94 \%$ .

Table 3: Effect of seasons on broiler performance

	Summer group	Winter group
Final body weight (gm)	$1740 \pm 0.93^b$	$2093 \pm 0.75^a$
Average feed intake (gm)	$3532 \pm 10.5^b$	$3975 \pm 6.5^a$
Food conversion rate	$2.03 \pm 0.07^a$	$1.9 \pm 0.00^a$
Mortality rate (%)	$6.5 \pm 0.94^b$	$3.5 \pm 0.08^a$

<sup>a,b</sup>Means with the different indices between groups are significantly different at  $p < 0.05$

**Anatomical measurement:**

**Arterial blood supply**

**A. tibialis cranialis:**

The cranial tibial artery (Figs.2 and 3/1); the largest terminal branch of the popliteal artery and it was considered as its direct continuation after the origin of the caudal tibial artery. It is the main arterial blood supply of the leg and foot and continued as the common dorsal metatarsal artery (Figs.2 and 3/6). The common dorsal metatarsal artery with the collateral branches of the distal third of the cranial tibial artery and some large veins formed multiple parallel vessels referred to as the rete tibialis cranialis (Fig.2/2). The branches of the rete tibialis cranialis communicated distally on the dorsal aspect of the hock joint forming another net termed rete tarsi dorsalis or rete tibiotarsale (Figs.2 and 3/3), from



which the arteries of the foot are detached. The rete tibiotarsale is playing a role in thermoregulation of the leg temperature in summer through heat dissipation due to the presence of extensive arteriovenous anastomosis.

#### **Arterial blood supply of the foot (shank and toes)**

The foot received its arterial blood supply from the common dorsal metatarsal artery (Figs.2 and 3/6) which is the direct continuation of the cranial tibial artery opposite to the level of the proximal end of the tarsometatarsus. It is communicated with the collateral branches of the distal third of the cranial tibial artery forming the *rete tarsi dorsalis* on the dorsal aspect of the hock joint. The *rete tarsi dorsalis* gives off the lateral and medial plantar tarsal arteries. The common dorsal metatarsal artery continues distally on the dorsal aspect of the metatarsus till its middle where it divides into lateral and medial dorsal metatarsal arteries.

#### **1. Aa. tarsi plantareslateralis et medialis:**

The lateral and medial plantar tarsal arteries (Figs.2/4 and 2/5); are given off from the lateral and medial aspects of the rete tarsi dorsalis respectively. Each plantar tarsal artery divided into an ascending and descending branch.

#### **2. Aa. metatarsi dorsalislateralis et medialis:**

The lateral (Figs.2 and 3/7) and medial (Figs.2 and 3/8) dorsal metatarsal arteries are considered as the distal termination of the common dorsal metatarsal artery. They descend on the corresponding dorsal surface of the tarsometatarsus and share in the formation of the plantar arterial arch (Fig.2/9) that which gives off most of the digital arteries.

#### **Aa. digitales:**

The majority of the digital arteries (Figs.2 and 3/10, 11, 12, 13) spring from the plantar arterial arch (Fig.2/9) while the rest of the digital arteries are detached from the medial and lateral dorsal metatarsal arteries. They course along the medial and lateral aspects of the corresponding digits and anastomose with the accompanied veins

#### **Venous drainage**

##### **V. tibialiscaudalis**

The caudal tibial vein (Fig. 4/1); is given off from the caudal aspect of the popliteal vein. It descends in company with the caudal tibial artery to drain the flexors of the leg. The caudal tibial vein does not exceed the level of the tibiotarsometatarsal joint as it anastomoses with the medial crural vein just proximal or at the same level with the preceding joint to give the medial plantar metatarsal vein (Fig. 4/4).

##### **V. tibialiscranialis**

The cranial tibial vein (Fig. 4/2); is the largest branch of the popliteal vein and it is considered as its continuation. It runs cranioventrally in company with the fibular artery through the proximal interosseous foramen, and then proceeds on the cranial aspect of the tibia. The cranial tibial vein continues as common dorsal metatarsal vein (Fig. 4/5).

##### **V. metatarsalisdorsaliscommunis**

The common dorsal metatarsal vein (Fig. 4/5); is the direct continuation of the cranial tibial vein just distal to the hock joint. At the middle third of the dorsal aspect of the tarsometatarsus, the common dorsal metatarsal vein divides into medial and lateral dorsal metatarsal veins (Figs.4/6 and 4/7), which are proceeded distally along the corresponding dorsal aspect of the tarsometatarsus till reaching the metatarsal pad.

### ***The venous drainage of the foot***

The venous blood of the foot was drained through the Arcusvenosusplantaris (venous plantar arch) (Fig.4/8) which is formed just proximal to the plantar aspect of the phalanges of the toes inside the metatarsal pad. The medial plantar metatarsal vein shared with the medial and lateral dorsal metatarsal veins in the formation of the arch that responsible for detaching some of the digital veins.

*Vv. Digitales* (Figs. 4/9, 1/10, 1/11, 1/12); some of the digital veins are directly detached from the venous plantar arch, while the rest of the digital veins came from the lateral and medial dorsal metatarsal and the medial plantar metatarsal veins. The digital veins are extensively anastomosed with the corresponding digital arteries to perform a role in the body thermoregulatory mechanism.

Exchange of heat between arteries and veins was considered to be of great importance in reducing heat because the large vein and artery run close to each other in the tibial region.

Anatomical adaptations favoring arteriovenous heat exchange consisted of the close apposition of arteries and veins in elaborate networks (rete tibiotarsale), which was an intermingled network of arteries and veins. Together these arteries and veins form a rete mirabile (fig.5 and 6/4) which responsible for heat loss. Most of the arteries in the pelvic limb were accompanied by veins, but the degree of arteriovenous contact was most extensive in the distal part of the tibial region. Sections of the cranial tibial vascular complex at this level showed a large artery, the cranial tibial artery (fig.5 and 6/1) and small collateral branch of the fibular artery, (fig.5 and 6/2) which were all in contact with two to four venae comitantes (fig.5 and 6/3).



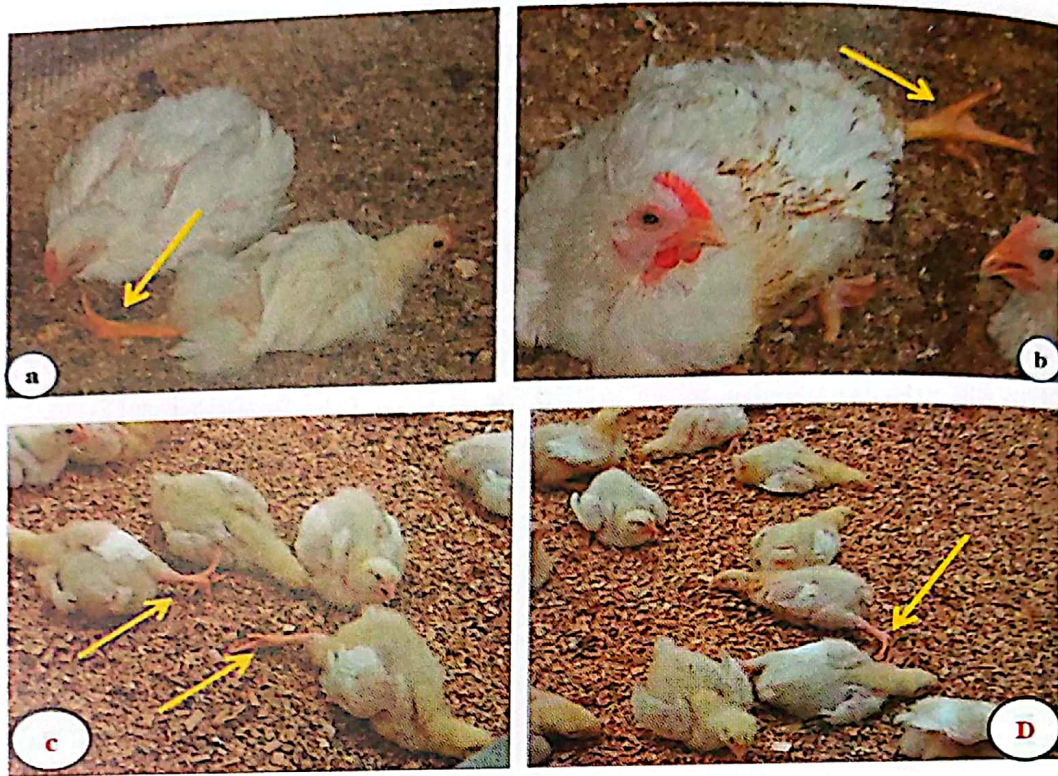


Fig. 1: Leg and wing stretch during lateral rest in summer group

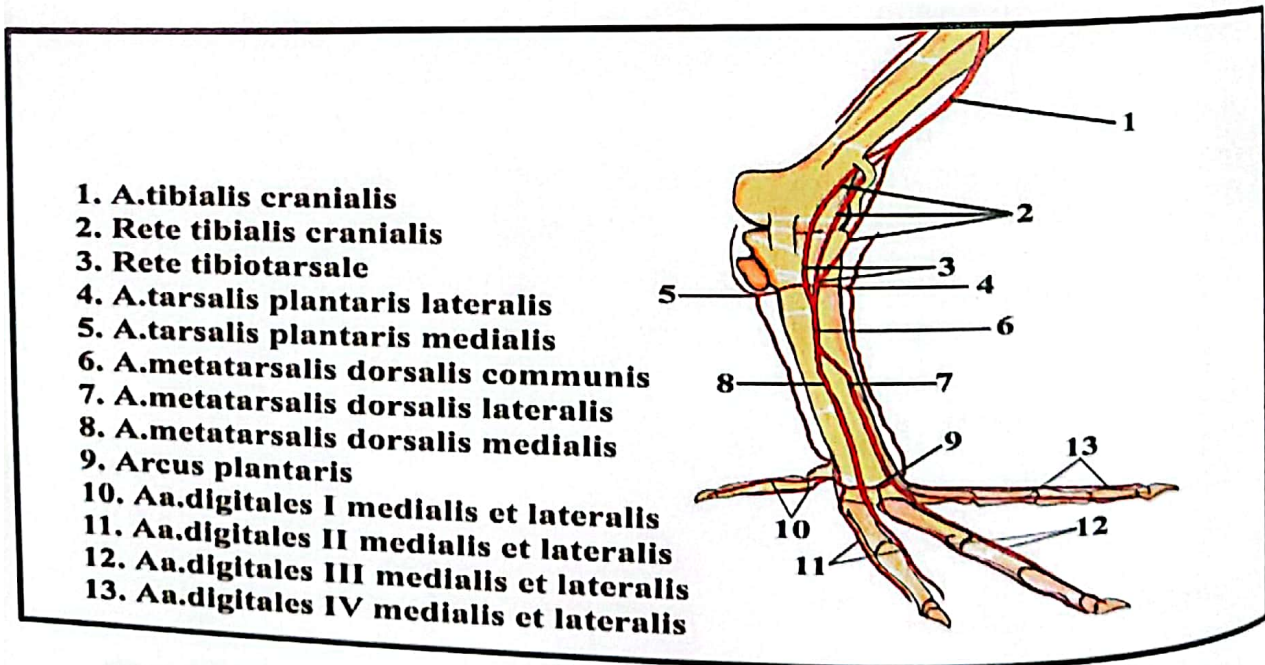
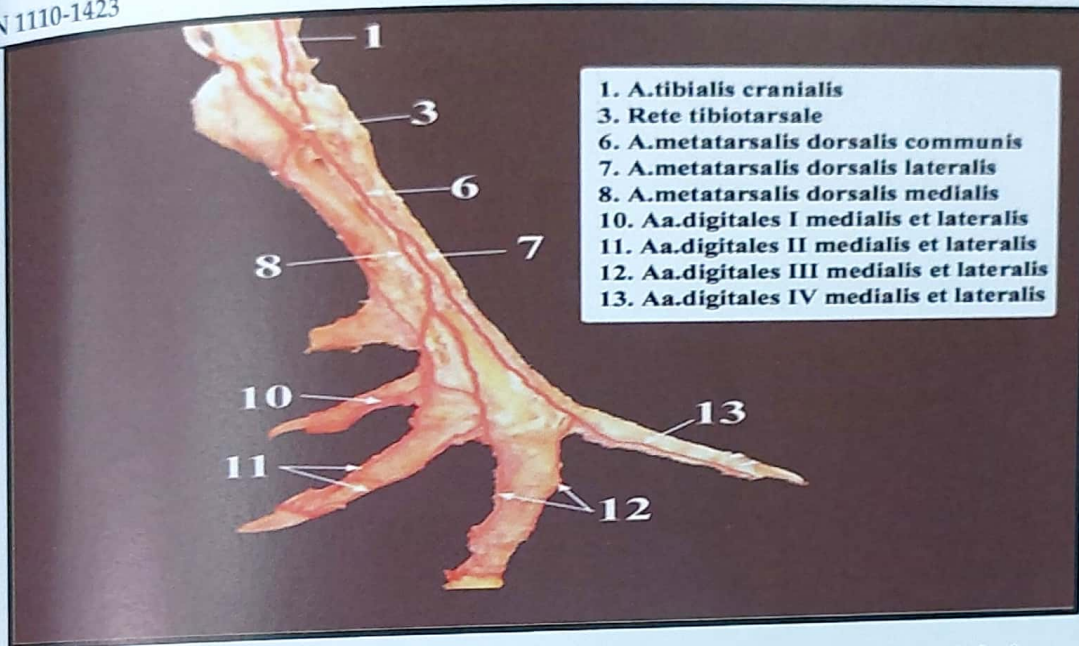


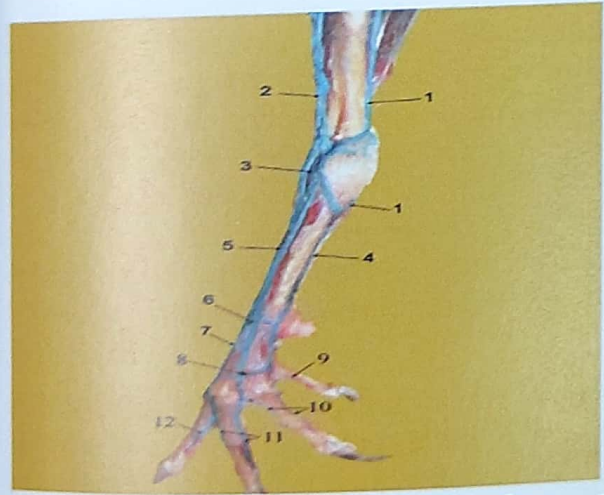
Fig 2. Arterial blood supply tibial region of pelvic limb, medial view, diagrammatic.





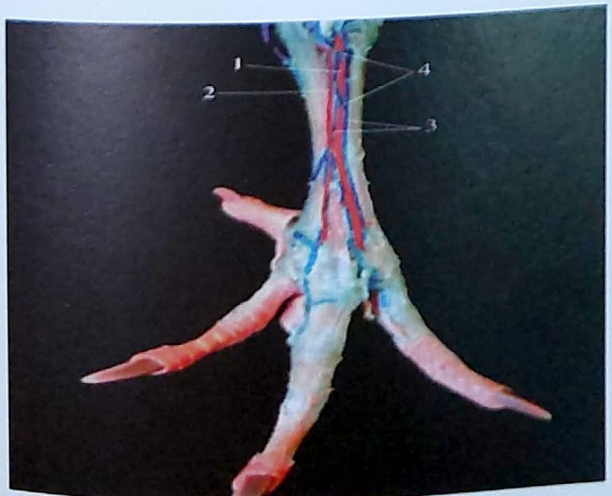
- 1. A.tibialis cranialis
- 3. Rete tibiotarsale
- 6. A.metatarsalis dorsalis communis
- 7. A.metatarsalis dorsalis lateralis
- 8. A.metatarsalis dorsalis medialis
- 10. Aa.digitales I medialis et lateralis
- 11. Aa.digitales II medialis et lateralis
- 12. Aa.digitales III medialis et lateralis
- 13. Aa.digitales IV medialis et lateralis

Fig. 3 .A photograph showing the arteries of left foot dorsomedial view.



- 1. V.tibialis caudalis
- 2. V.tibialis cranialis
- 3. Rete tibiotarsale
- 4. V.metatarsalis plantaris medialis
- 5. V.metatarsalis dorsalis communis
- 6. V.metatarsalis dorsalis medialis
- 7. V.metatarsalis dorsalis lateralis
- 8. Arcus venosus plantaris
- 9. V.digitalis I lateralis
- 10.V.digitalis II medialis et lateralis
- 11 . V.digitalis III medialis et lateralis
- 12. V.digitalis IV medialis

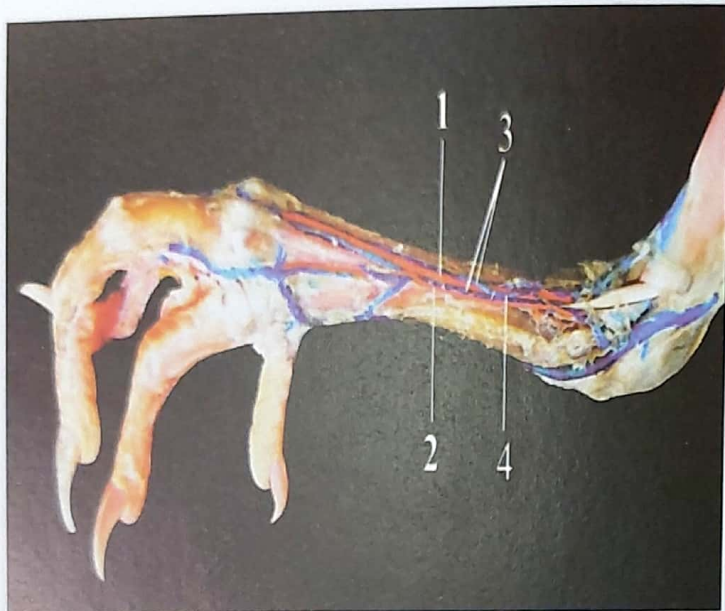
Fig 4 .A photograph showing the venous drainage of left foot lateral view.



- 1-A. tibialis cranialis
- 2-R.collateralis et A.fibularis
- 3- Venae comitantes

Fig 5 .A photograph showing the Arterio-venous Anastomosis in pelvic limb





- 1- A. tibialis cranialis
- 2- R. collateralis et A. fibularis
- 3- Venae comitantes
- 4- Rete tibiotarsale (Rete mirabile)

Fig 6 .A photograph showing the Arterio-venous Anastomosis in pelvic limb

### Discussion

The results revealed that winter group chicken showed more feeding time and higher feed intake than summer group this reflected on performance of birds in the higher body weight, lower feed conversion rate and lower mortality rate in the winter group than summer one. These results related to the side effect of summer heat stress on birds according to Dagher (2009) who referred that the most important factor affecting performance in broilers subjected to high temperature was reduced feed intake. While summer group showed higher drinking behaviour than winter group, these related to need of summer stressed birds to drink more water as water played an important role in cooling broilers.

Concerning to welfare behaviour index, winter group showed higher resting, preening, and body scratching these means that birds felt a sense of comfort during winter season compared to summer season. While leg and wing stretch in higher during summer than in winter and in the same time birds during summer recorded frequent posture during rest, that birds laying laterally in one side and extend the limb of the opposite site. This behaviour related to anatomical feature of the pelvic limb of birds that increase exposure of ventral aspect of limb to air as a method of behavioral adaptation of birds to summer heat stress according to Gonzalez and Leeson (2006) and Bogin et al., (1996 a, b). The results of this study are parallel with the results of Scholander (1955) revealed that, return of the blood through the superficial veins would enhance heat dissipation to the environment.

High-temperature tolerance relied on physiological and behavioral adaptation to dissipate heat. When heat stressed in a metabolic chamber, regulated their body temperature only by evaporation and reduced insulation, the chamber being too small to allow postural adjustments that increase heat loss as reported by Arad and Bernstein (1988) in turkey vultures. The feet of birds are excellent dissipators of excess body heat (Steen and Steen 1965, Bemstein 1974, Kilgore and Schmidt-Nielsen 1975, Baudinette et al., 1976).



The cranial tibial artery in the chicken was the largest terminal branch and the direct continuation of the popliteal artery after giving off the caudal tibial artery, a result resembled that demonstrated by El-Gmmal., (2012) in chicken, Mcleod et al., (1964) in the domestic fowl, Can et al., (2010) in Japanese quail and El-Nahla et al., (2010) in the ostrich. Koch (1973) in the domestic fowl stated that the cranial tibial artery divided proximal to the tarsal joint into two branches, which supplied the toes.

The present investigation in the chicken revealed that the common dorsal metatarsal artery was the continuation of the cranial tibial artery after it crossed the flexor surface of the hock joint, and then continued distally on the tarsometatarsus to terminate at the base of the digits by forming the digital arteries, a result which agreed with that of Swielim et al., (2012) in chicken, Mcleod et al., (1964), Baumel (1975b), Nickel et al., (1977) and Baumel et al., (1993) in the domestic fowl and El-Nahla et al., (2010) in the ostrich. Mcleod et al., (1964) in the domestic fowl named this vessel as the great metatarsal artery.

Our study and Midtgard (1981) revealed that multiple, plexiform counter-current veins that contribute to the rete tibiotarsale are derived from fibular and cranial tibial veins. The rete tibiotarsale (rete mirabile tibiotarsale) was defined by Midtgard (1981) in many different birds as the venous rete was intermingled with an arterial rete that useful for heat dissipation.

The present work and Swielim et al., (2012) in chicken, demonstrated that some of the digital veins were directly detached from the venous plantar arch, while the rest of the digital veins came from the lateral and medial dorsal metatarsal and the medial plantar metatarsal veins independently, these results was important according to Nickel et al., (1977) who stated these parts of the limbs are exposed to severe temperature changes, and they therefore have arteriovenous anastomosis with a hemodynamic and thermoregulatory action.

### Conclusion

Based on the results of this study; it was concluded that when environmental temperature exceeding the thermoneutral zone of bird; a number of behavioral responses was occurred depending on their anatomical structural and this contributed to their ability to resist heat stress.

### Acknowledgement

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## موسمية التكيف السلوكي لدجاج التسمين مع التفسير التشريحي لبعض السلوكيات أثناء الإجهاد الحراري في الصيف

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أجريت هذه الدراسة لمعرفة التغيرات السلوكية الموسمية في دجاج التسمين وإجراء التفسير التشريحي لبعض من هذه السلوكيات. تم استخدام ٢٠٠ طائر من دجاج التسمين؛ مجموعة تم تربيتها في الشتاء (١٠٠ طائر) ومجموعة تم تربيتها في الصيف (١٠٠ طائر) تم تقسيم هذه المجموعة إلى مكرارين ٥٠ طائر لكل منهما. تمت التربية لفترة ٣٥ يوم تم خلالها تسجيل الأنماط السلوكية المختلفة بالملاحظة اليومية ٣ مرات كل مرة ١٠ دقائق لكل مكرر؛ بطريقة المسح الشامل. تم تسجيل السلوكيات التالية؛ سلوك تناول الطعام؛ الشرب؛ فرد الأجنحة والأرجل؛ الهنمة؛ سلوك الراحة. بالإضافة إلى معايير الأداء من الوزن النهائي للجسم، إجمالي استهلاك العلف، ونسبة التحويل الغذائي ومعدل الوفيات. تم إجراء توصيف تشريحي للإمداد الدموي والصرف الوريدي للأرجل في دجاج التسمين من خلال حقن اللاتكس نيوبرين (المائل المطاطي اللين) الملون باللون الأحمر للشريان واللون الأزرق للأوردة؛ بالإضافة لتوصيف التقم الشرياني الوريدي من خلال تشريح ١٠ طيور من كل مجموعة. وقد لعبت النتائج عا اختلافات معنوية في الأنماط السلوكية بين المجموعات المختلفة وكانت قيمة  $P \leq 0.05$  وكان سلوك الراحة في الصيف أعلى  $33 \pm 0.94\%$  وأيضا سلوك فرد الأرجل والأجنحة أعلى في مجموعة الصيف عنة في الشتاء. بينما في معايير الأداء أعطت مجموعة الشتاء فروق معنوية أعلى من مجموعة الصيف حيث حققت مجموعة الشتاء أعلى متوسط وزن نهائي  $2093 \pm 0.75$  جم وفي نفس الوقت أعطت أقل متوسط استهلاك علف  $3532 \pm 10.5$  جم؛ وتم تفسير زيادة سلوك الراحة وفرد الأرجل في الصيف من خلال الوصف التشريحي للإمداد الدموي والصرف الوريدي للأرجل بالإضافة لإثبات التقم الشرياني الوريدي بدوره في تنظيم درج حرارة الجسم والحفاظ علي درجة حرارة الطائر في المعدل الطبيعي.