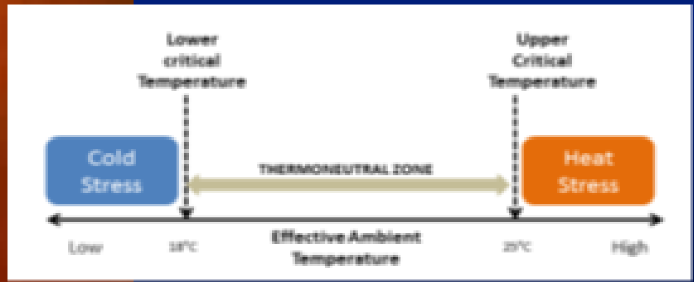
HEAT STRESS IN POULTRY

Strategies to improve performance during heat stress Using good management practices and nutrition



By Dr. Reza Vakili
Poultry nutritionist

Contents:

- Introduction
- Reproductive system
- Heat stress
- Heat stress on physiology of broiler and laying hen

Global spread of the domestic chicken

TABLE 1.1 Global Spread of the Domestic Chicken

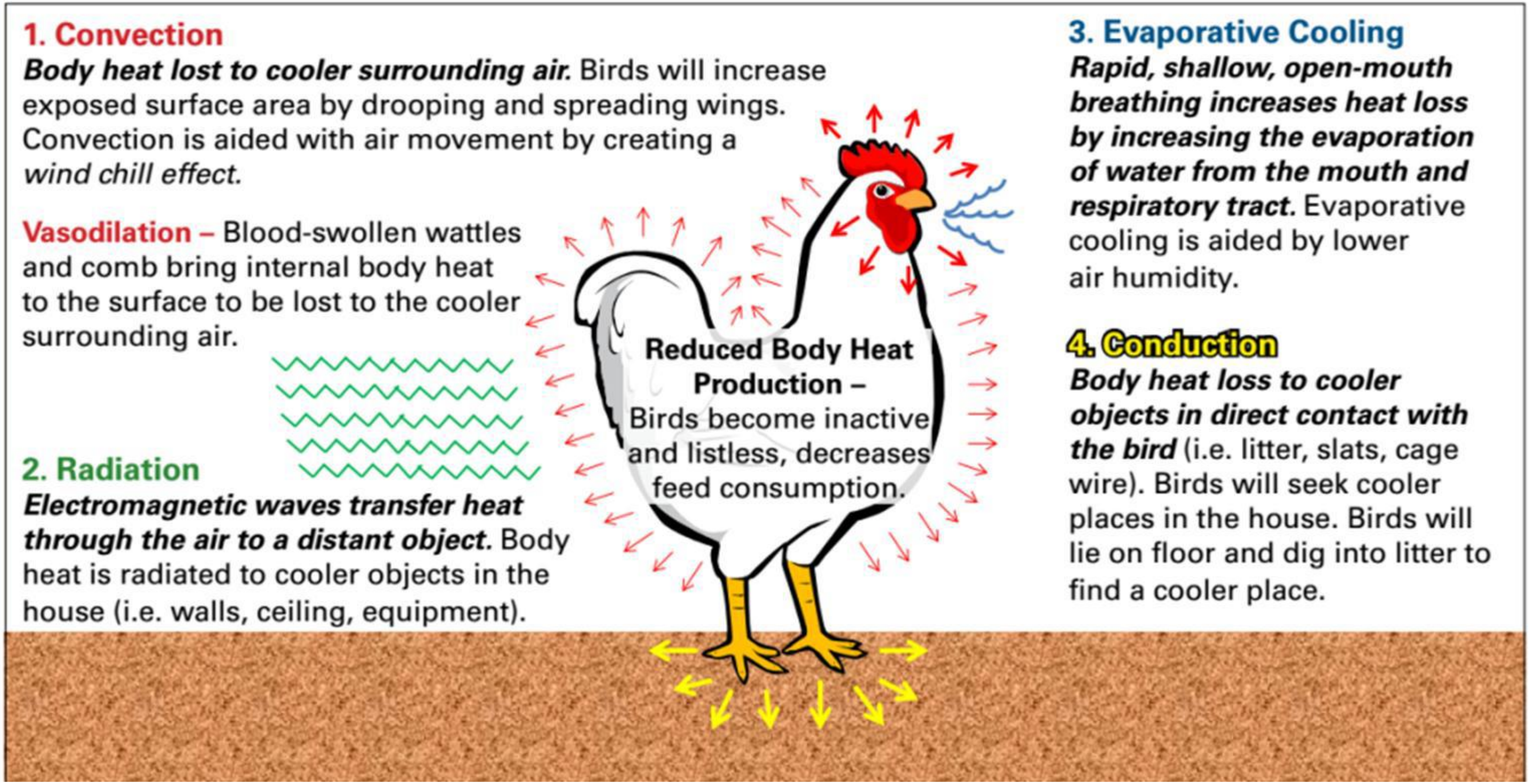
Estimated Time	Origin	New Area	References
Post 6000 BC	China	Surrounding nations	West and Zhou (1989)[a]
Post 2500 BC	Indus valley	Numerous areas	Zeuner (1963)[b]
1650 BC	Asia (probable)	East Africa	Mwacharo et al. (2013)[c]
About 1000 BC	Indus valley (probable)	Persia and Mesopotamia	Crawford (1990)[d]
After 1000 BC	Persia and Mesopotamia	Mediterranean regions, Rome	Crawford (1990)[d]
Pre 1200 BC	Uncertain	Some European locations	Yamada (1988)[e]
1200–550 BC	Uncertain	Europe	Yamada (1988)[e]
1000 BC	Southern Asia	Polynesia	Storey et al. (2012)[f]
End of BC Era	The Roman Empire	Europe and England	Yamada (1988)[e]
1500 AD	Europe	New World	Yamada (1988)[e]
1500 AD	Spanish traders	Some Polynesian areas, South America	Thompson et al. (2014)[g]

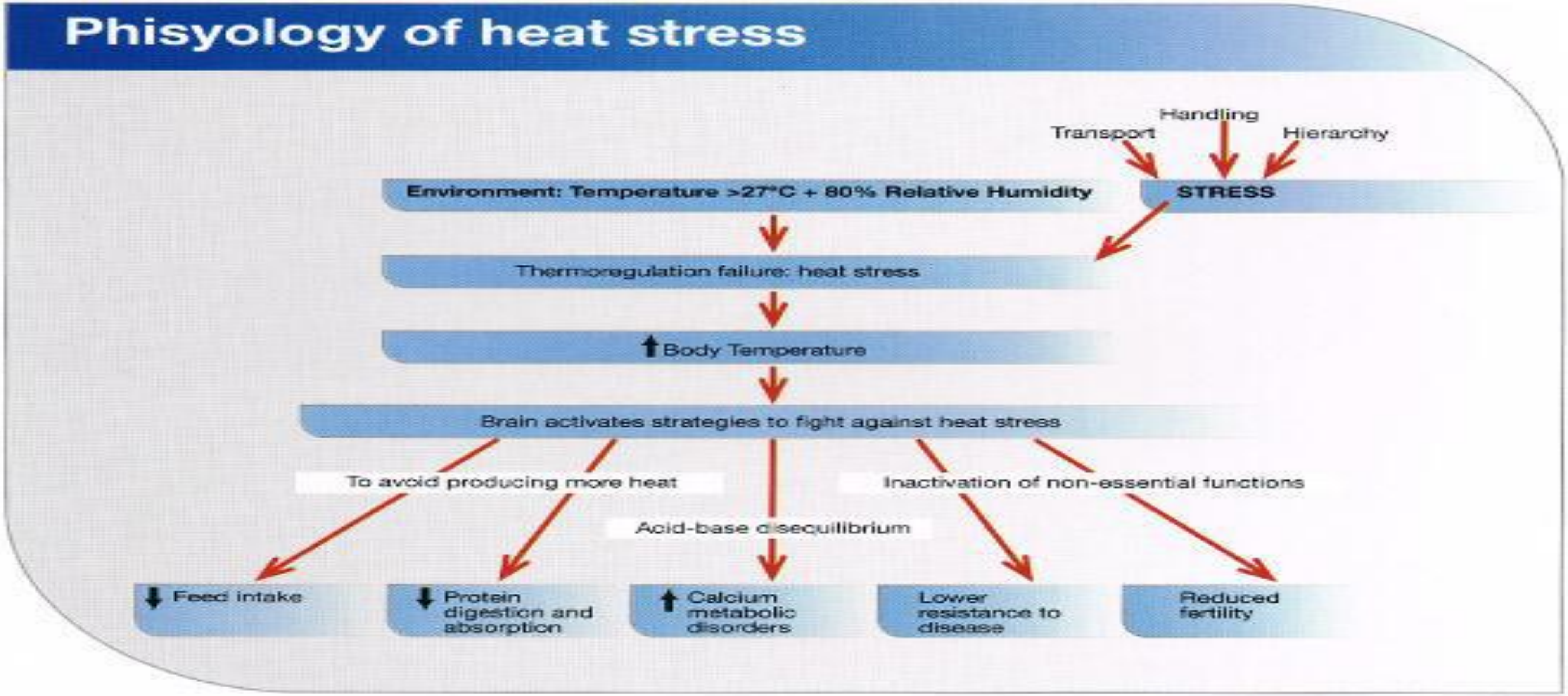
[a] *West, B., Zhou, B.X., 1989. Did chickens go north? New evidence for domestication. Worlds Poult. Sci. J. 45, 205–218.*
[b] *Zeuner, F.E., 1963. A History of Domestic Animals. Harper and Row Publication, New York, NY, United States.*
[c] *Mwacharo, J.M., Bjørnstad, G., Han, J.L., Hanotte, O., 2013. The history of African village chickens: an archeological and molecular perspective. Afr. Archaeol. Rev. 30, 97–114.*
[d] *Crawford, R.D., 1990. Origin and history of poultry species. In: Crawford, R.D. (Ed.), Poultry Breeding and Genetics. Elsevier Publication, Amsterdam, The Netherlands, pp. 1–18.*
[e] *Yamada, Y., 1988. The contributions of poultry science to society. Worlds Poult. Sci. J. 44, 172–178.*
[f] *Storey, A.A., Athens, J.S., Bryant, D., Carson, M., Emery, K., deFrance, S., Higham, C., Huyen, L., Intoh, M., Jones, S., Kirch, P.V., Ladefoged, T., McCoy, P., Morales-Muñiz, A., Quiroz, D., Reitz, E., Robins, J., Walter, R., Matisoo-Smith, E., 2012. Investigating the global dispersal of chickens in prehistory using ancient mitochondrial DNA signatures. PLoS One 7, e39171.*
[g] *Thomson, V.A., Lebrasseur, O., Austin, J.J., Hunt, T.L., Burney, D.A., Denham, T., Rawlence, N.J., Wood, J.R., Gongora, J., Girdland Flink, L., Linderholm, A., Dobney, K., Larson, G., Cooper, A., 2014. Using ancient DNA to study the origins and dispersal of ancestral Polynesian chickens across the Pacific. Proc. Natl. Acad. Sci. 111, 4826–4831.*

Birds are ‘heat stressed’ if they have difficulty achieving a balance between body heat production and body heat loss.

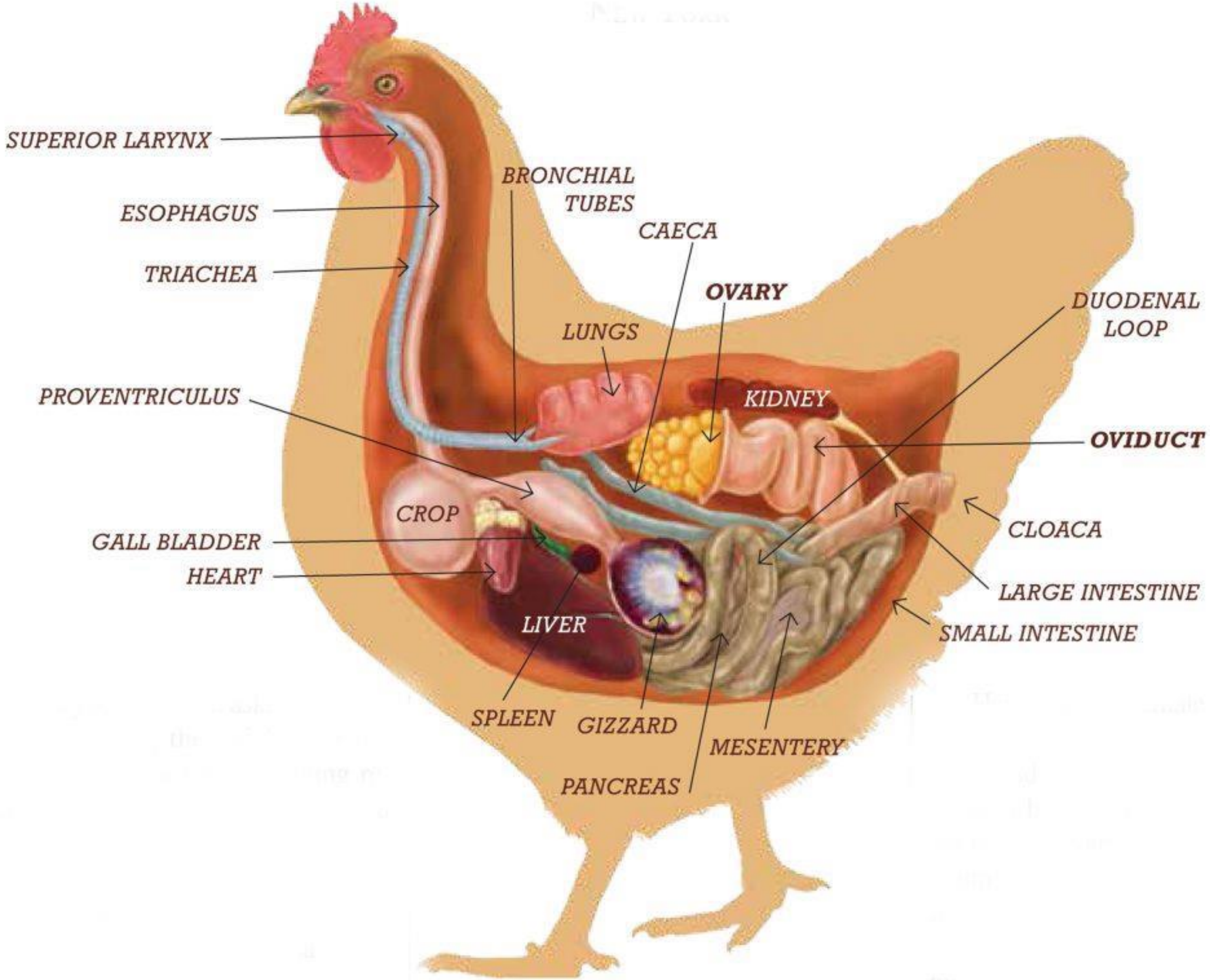
THERMOREGULATION OF THE HEN

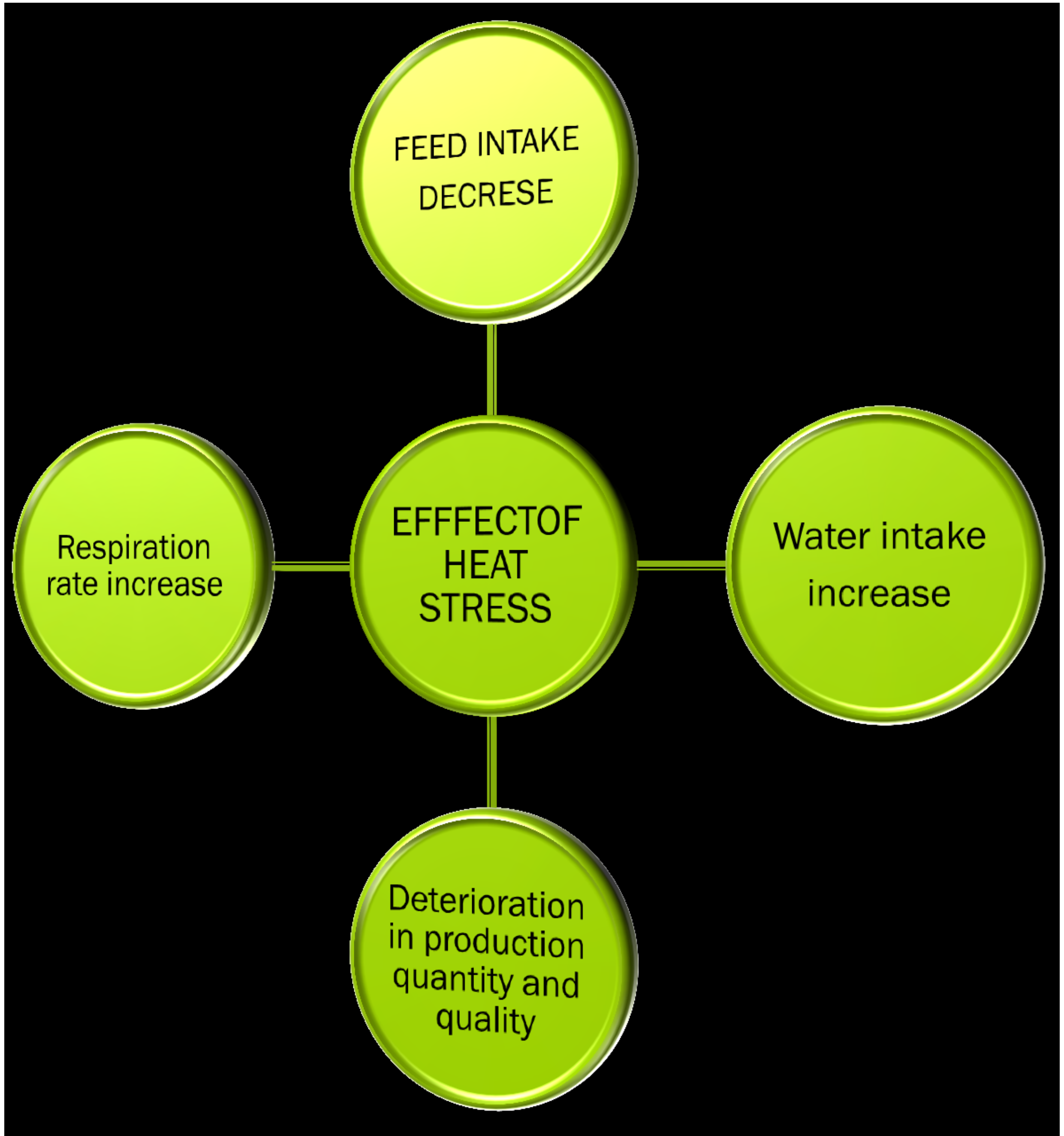
Excess body heat is removed by four different mechanisms (see Figure 1).





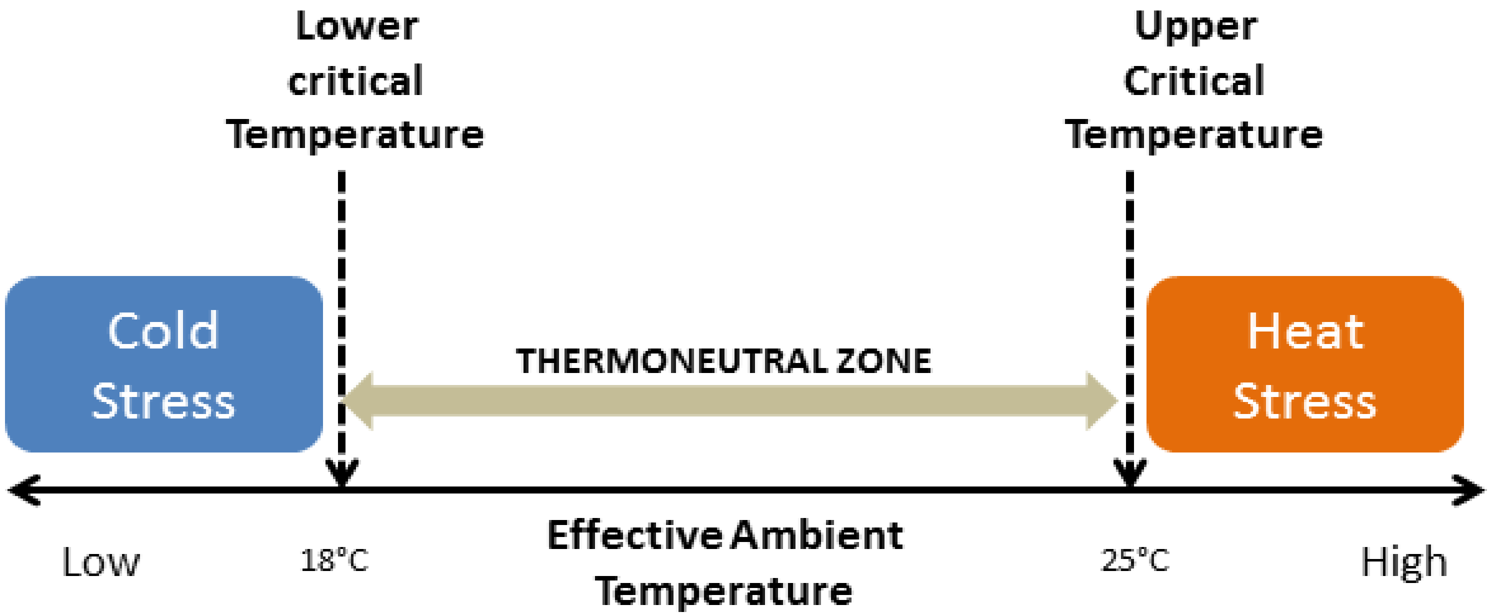
Phisyology of heat stress
Handling
Transport
Hierarchy
Environment: Temperature >27°C + 80% Relative Humidity
STRESS
Thermoregulation failure: heat stress
↑ Body Temperature
Brain activates strategies to fight against heat stress
To avoid producing more heat
Inactivation of non-essential functions
Acid-base disequilibrium
↓ Feed intake
↓ Protein digestion and absorption
↑ Calcium metabolic disorders
Lower resistance to disease
Reduced fertility


SUPERIOR LARYNX
ESOPHAGUS
TRIACHEA
BRONCHIAL TUBES
CAECA
OVARY
LUNGS
DUODENAL LOOP
PROVENTRICULUS
KIDNEY
OVIDUCT
CROP
CLOACA
GALL BLADDER
HEART
LARGE INTESTINE
LIVER
SMALL INTESTINE
SPLEEN
GIZZARD
MESENTERY
PANCREAS

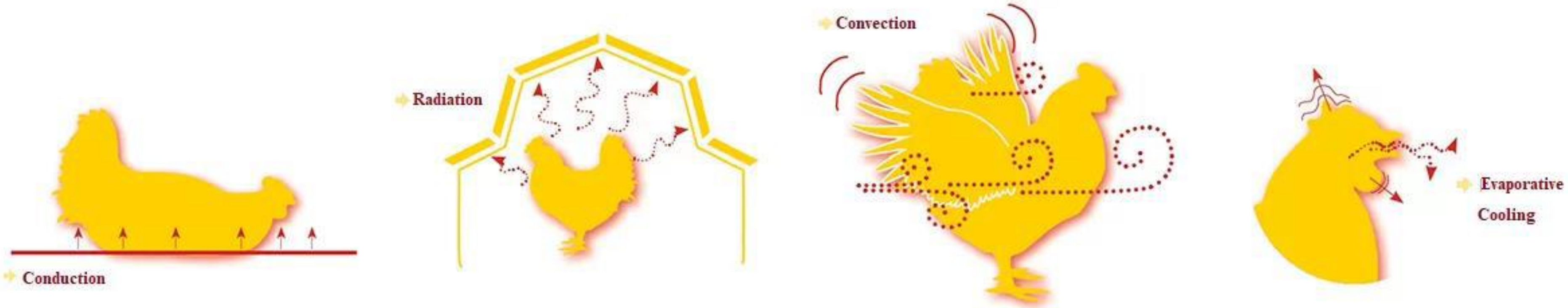

FEED INTAKE DECRESE
Respiration rate increase
EFFFECTOF HEAT STRESS
Water intake increase
Deterioration in production quantity and quality

-Animals:
Cold-blooded (heterothermic)
Warm-blooded (homeothermic)
-The temperature of newly hatched chick is 39.7 ^{0}C

-For maximum production, the body temperature must remain at approximately 41.1 ^{0}C


Lower
critical
Temperature
Upper
Critical
Temperature
Cold
Stress
THERMONEUTRAL ZONE
Heat
Stress
Low
18°C
Effective Ambient
Temperature
25°C
High

Heat stress



Conduction
Radiation
Convection
Evaporative
Cooling

The temperature-humidity index (THI) = heat or stress index

www.hyline.com

TEMPERATURE AND HUMIDITY STRESS INDEX FOR COMMERCIAL LAYING HENS
(HEAT STRESS INDEX = 0.6 X DRY BULB TEMPERATURE + 0.4 X WET BULB TEMPERATURE)

Relative Humidity (%)

Temperature °F	°C	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
68	20	63	63	63	64	64	64	64	65	65	65	66	66	66	66	67	67	67	67	68	68
72	22	64	65	65	66	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72
75	24	66	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74	75	75
79	26	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	77	77	78	78	79
82	28	70	70	71	72	72	73	74	74	75	76	76	77	78	78	79	80	80	81	82	82
86	30	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
90	32	73	74	75	76	77	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90
93	34	75	76	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90	91	92	93
97	36	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97
100	38	78	79	81	82	83	84	85	86	88	89	90	91	92	93	95	96	97	98	99	100

Bird Comfort Zone (heat index < 70): No action needed; a good time to prepare for future hot weather.

Alert (heat index 70–75): Begin taking heat stress reduction measures in the flock; increase ventilation rate; increase fan speed and use foggers (run foggers based on relative humidity). Monitor bird behavior for signs of heat stress; ensure drinker and ventilation systems are functioning properly.

Danger (heat index 76–81): Heat stress conditions exist; take immediate measures to reduce heat stress in the flock. Increase ventilation rate in closed houses and use evaporative cooling based on relative humidity; in open houses run stir fans and misters. Adjust nutrient density of bird's diet to match any reduction in feed consumption. Move air over the birds at a minimum velocity of 1.8–2.0 meters/second. Periodically flush water lines with cooler water. Closely monitor flock behavior. Maximize nighttime cooling.

Emergency (heat index > 81): Extreme heat stress conditions exist; avoid handling birds for transfer or vaccination. Do not feed during the hottest part of the day. Decrease light intensity to reduce bird activity and body heat production.

Figure 2. Adapted from Temperature and Humidity Stress Index for Laying Hens. Xin, Hongwei and Harmon, Jay D., "Livestock Industry Facilities and Environment: Heat Stress Indices for Livestock" (1998) Agriculture and Environment Extension Publications. Book 163, Iowa State University.

Heat Stress

Kim et al (2020) reported:

age: 60-week-old laying hen for 28 days

1-Temperature 26⁰C , Humidity 70% ($T_L H_H$75)

2-Temperature 30⁰C , Humidity 30% ($T_H H_L$75)

No differences

Egg production
Egg quality
Blood chemical parameters
Heterophilto lymphocyte ratio
Corticosterone

Kim, d., Lee, y., and kin, S. 2021. The impact of temperature and humidity on the performance and physiology of laying hens. Animals, 11,56.

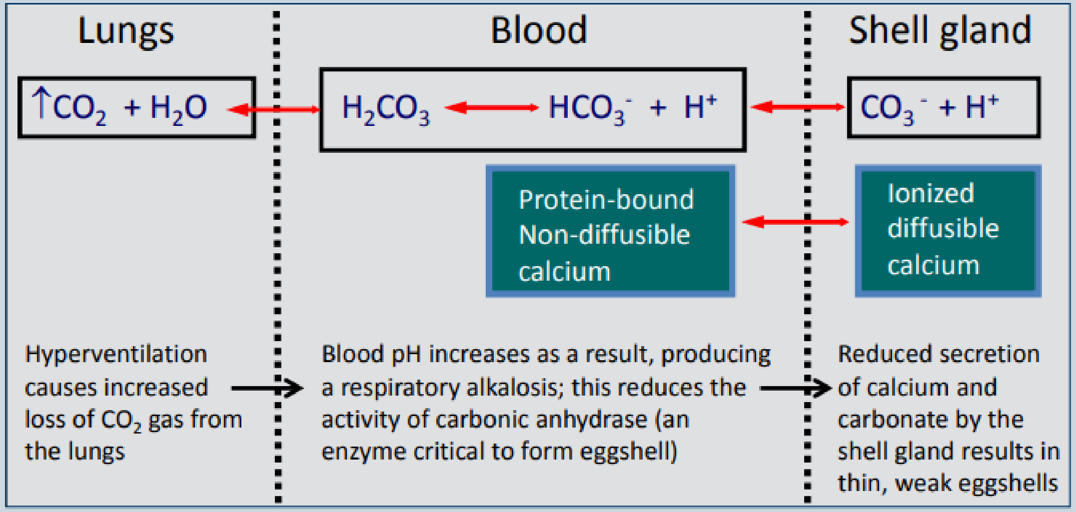
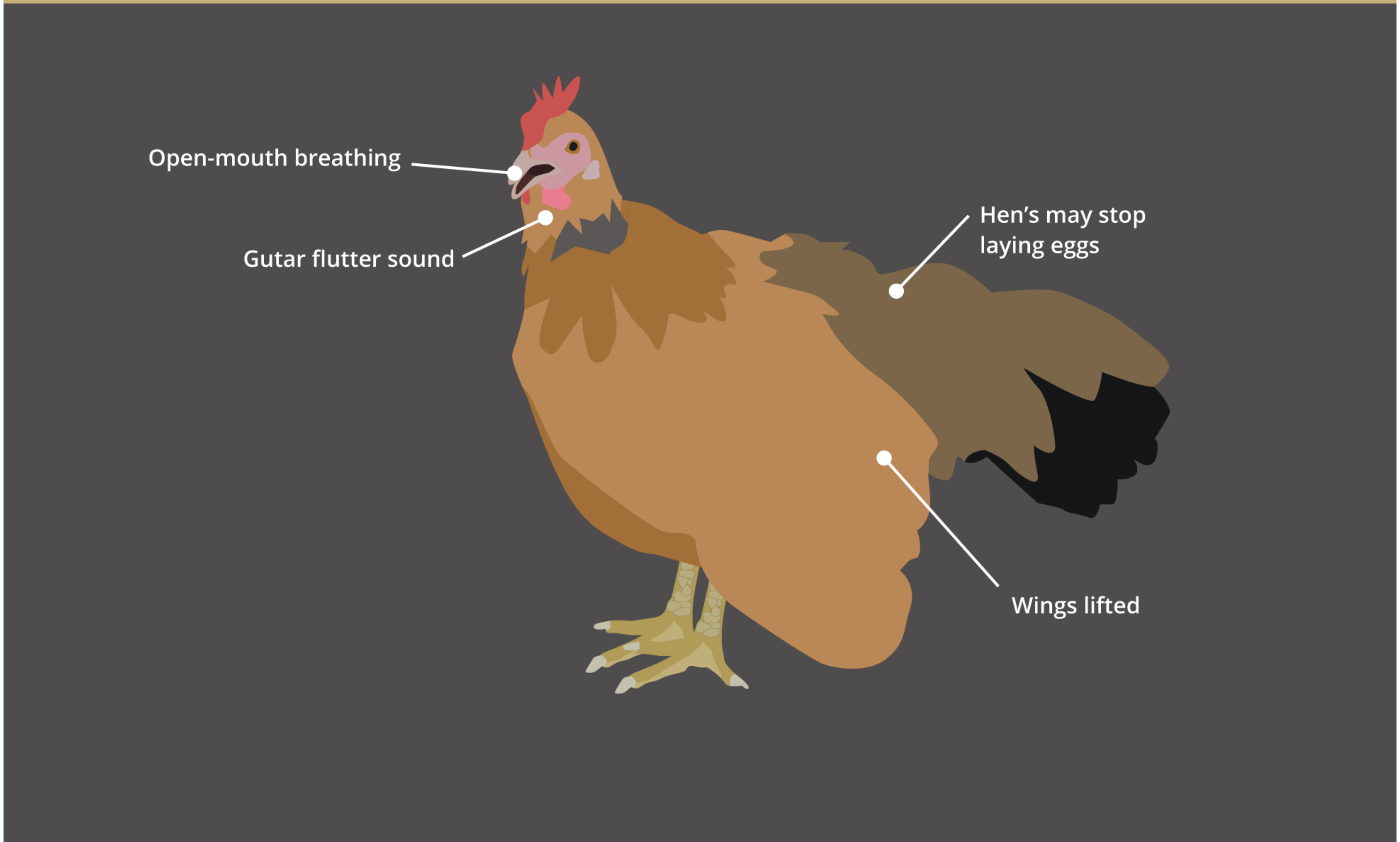


Figure 3. Demonstration of acid/base balance disruption caused by heat stress.

RESTORING THE ACID/BASE BALANCE

Potassium chloride, ammonium chloride or sodium bicarbonate (2–3 kg / MT of feed) can replace electrolytes lost during heat stress and encourage consumption of water. These treatments have shown beneficial in reducing mortality in acutely heat-stressed flocks.

Signs of a Heat-Stressed Chicken



Hormone regulations in heat stress

- Antidiuretic hormone(ADH)
- Corticosterone hormone
- Catecholamines
- FSH & LH
- Thyroid hormones
- Heat shock proteins

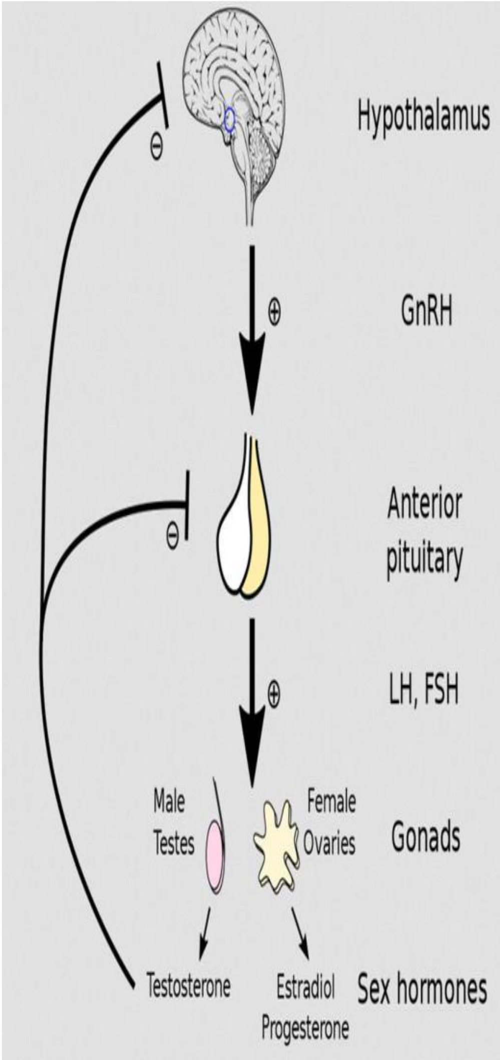
Heat Stress:

When subjected to heat stress:

- **Increasingthesecretionofcorticosterone(CORT),amajorstresshormoneinchickens,viaactivationofthehypothalamic-pituitary-adrenal(HPA)axis.**

- **Thesynthesisandmetabolicactivityofcarbonicanhydraseiscontrolledbyestrogensandprogesterone.**

- **Heatstresssuppressestheactivityofthethyroidgland,whichpreventstheformationoftheactiveformofvitaminD3inthekidneys.**



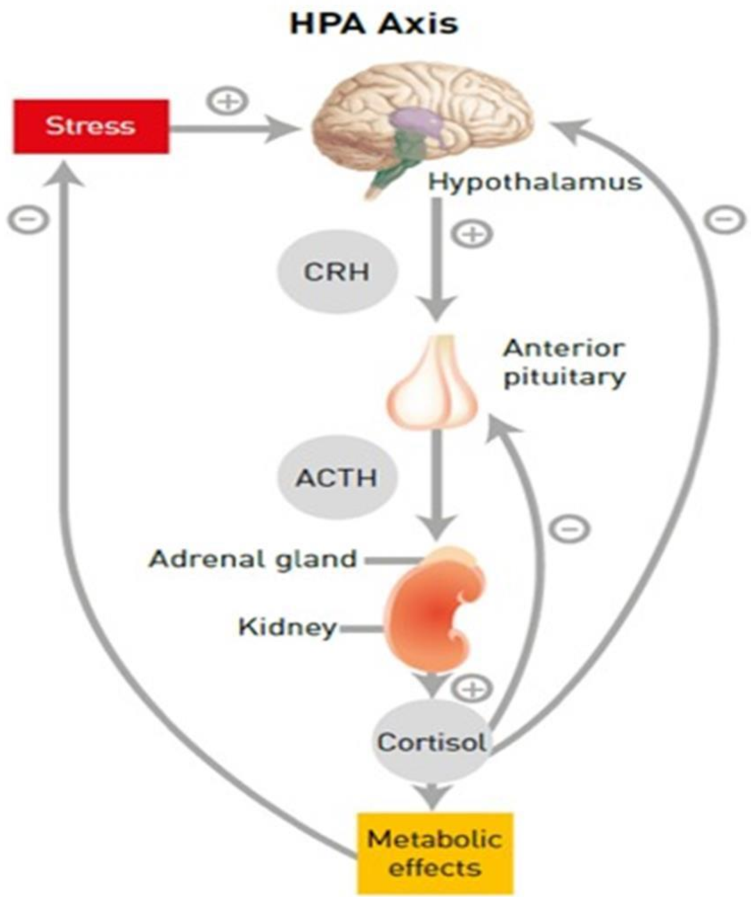
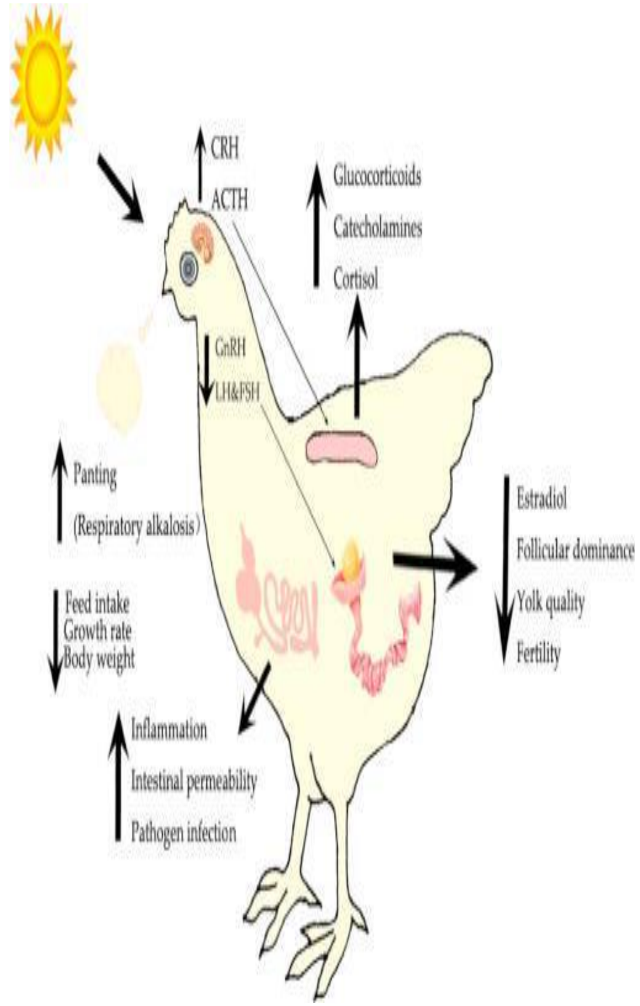


Figure 1. Effect of stress on HPA-axis (S. Hiller-Sturmhöfel, 1998)



Heat Stress

When subjected to heat stress:

- Calbindin-D28k is the transfer of ionized calcium from the intestine to the shell gland . Decrease in the secretion of estrogens are involved in the induction of synthesis of calbindin-D28K.

- Decrease in blood flow to the egg production organs.

- Increase the excretion of certain minerals (phosphorus, potassium, sulfur, copper, zinc, molybdenum and magnesium).

Barrett,W.,Rowland,K.,Schmidt,C.,….AndPersia,E.2019.Effectsofacuteandchronicheatstressontheperformance,eggquality,bodytemperature,andbloodgasparametersofl ayinghens.PoultryScience.98:6684-6692.
Kavtarashvili,A.,andBuyarov.2021.Thereasonsforthedeteriorationofchickeneggshellqualityathightemperatures:areview.E3SWebConferences247,01015.

Heat Stress

- Na^{+}, k^{+} and Cl^{-}

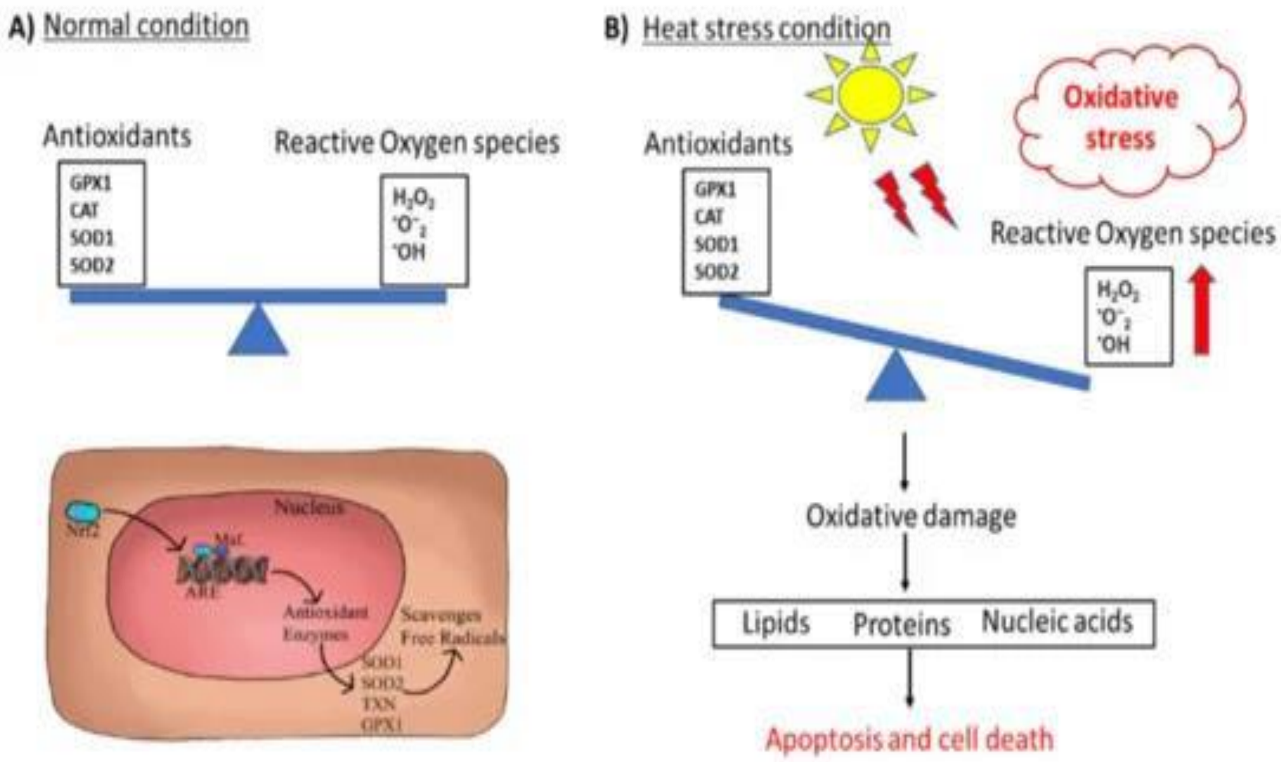
- layinghenssignificantlyreducetheirfeedintake(38.8%),layingperformance(5.0%),bodyweight(5.2%),smallintestineweight(22-23%)andtheabsorbingsurfaceoftheintestinalvilli(19%)at24weeksofage.

- imbalancebetweentheproductionofreactiveoxygenspecies(ROS)andantioxidantdefensesystemwhichresultsinthedamagestotheepitheliumandintestinalmucosa.

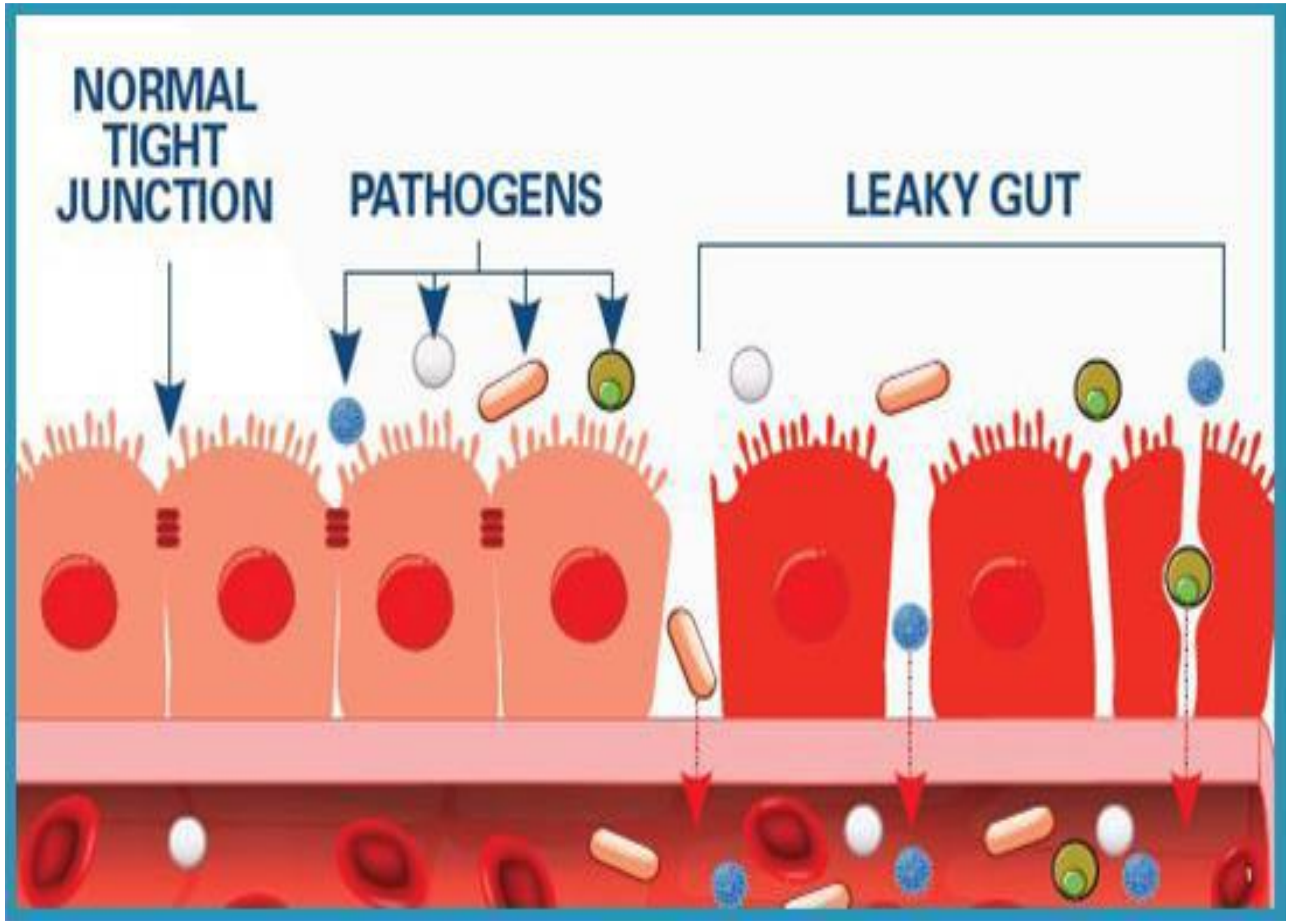
- IncreasepHofgastrointestinal.

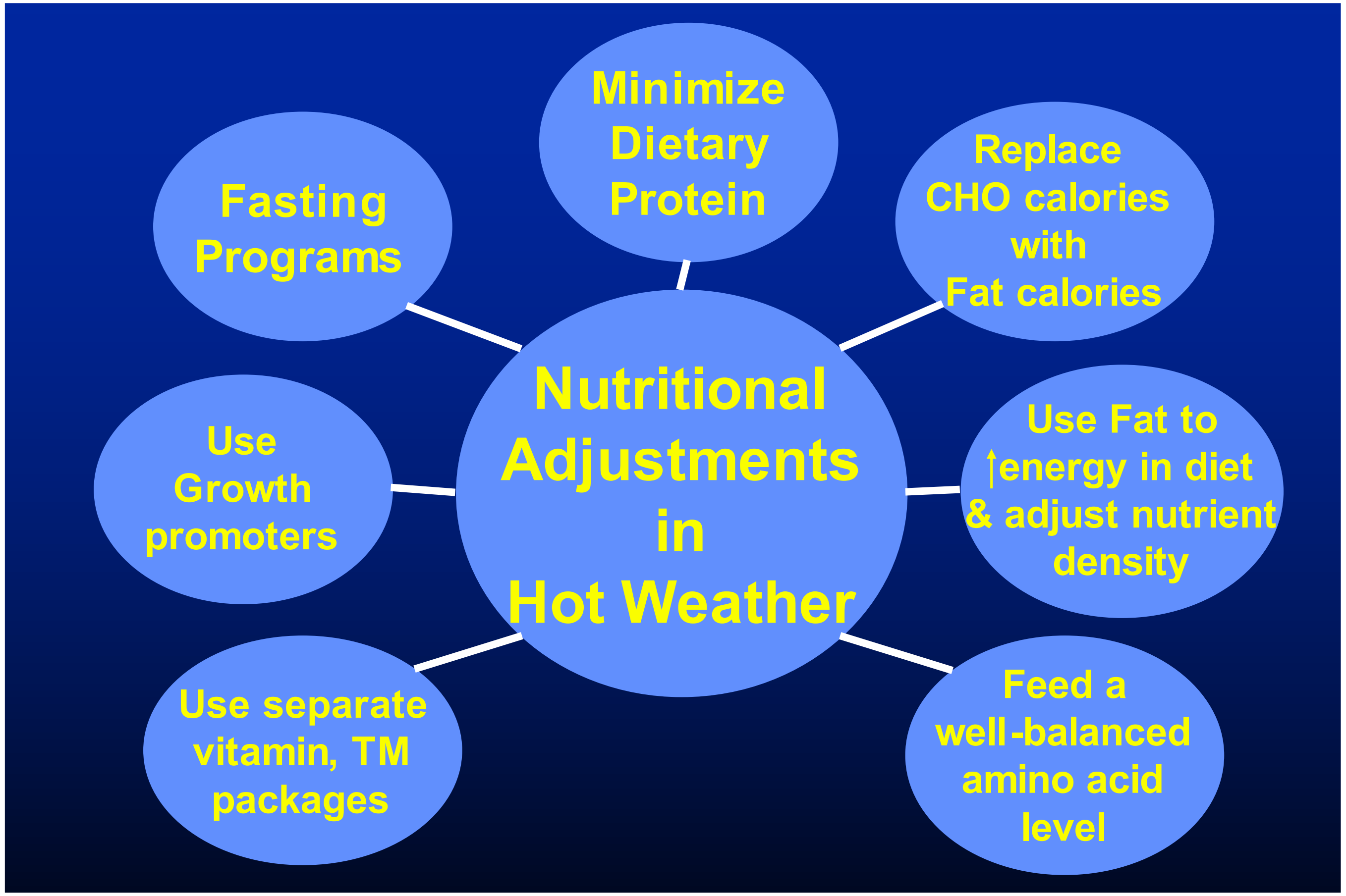
- Increaseboneresorptionandphosphate&decreasecaandbicarbonateineggshellgland

Barrett, W., Rowland, K., Schmidt, C., …. And Persia, E. 2019. Effects of acute and chronic heat stress on the performance, egg quality, body temperature, and blood gas parameters of laying hens. Poultry Science. 98:6684-6692.
Kavtarashvili, A., and Buyarov. 2021.The reasons for the deterioration of chicken eggshell quality at high temperatures:areview. E3S Web Conferences 247,01015.



A) Normal condition
Antioxidants
GPX1
CAT
SOD1
SOD2
Reactive Oxygen species
H_2O_2
$^{\cdot}O^{-}_{2}$
$^{\cdot}OH$
Nucleus
Nrf2
Maf
ARE
Antioxidant Enzymes
Scavenges Free Radicals
SOD1
SOD2
TXN
GPX1
B) Heat stress condition
Oxidative stress
Antioxidants
GPX1
CAT
SOD1
SOD2
Reactive Oxygen species
H_2O_2
$^{\cdot}O^{-}_{2}$
$^{\cdot}OH$
Oxidative damage
Lipids
Proteins
Nucleic acids
Apoptosis and cell death


NORMAL TIGHT JUNCTION
PATHOGENS
LEAKY GUT


Nutritional Adjustments in Hot Weather
Minimize Dietary Protein
Fasting Programs
Replace CHO calories with Fat calories
Use Growth promoters
Use Fat to ↑energy in diet & adjust nutrient density
Use separate vitamin, TM packages
Feed a well-balanced amino acid level

Beneficial Heat Stress Dietary Changes

Decrease
Heat Increment
“less waste heat”

USE FAT CALORIES

IMPROVE AMINO ACID BALANCE

HEAVIER BREEDS OF BIRDS (BROILERS) ARE NOT ABLE TO COPE WITH HEAT STRESS AS WELL AS LIGHTER BREEDS OF BIRDS (LEGHORNS)

FACT

Dietary use of fat will improve poultry performance in hot weather.

…However…

The response to dietary fat requires adequate amino acid intake.

-Supplementation with α-tocopherol has proven to be an effective measure to prevent lipid oxidation (Lin et al., 1989; Ahn et al.,
1995; Cortinas et al., 2001) and to improve sensory quality (O'Neill et al., 1998, Bou et al., 2001) of poultry meat. Because α-tocopherol protects PUFA from lipid oxidation, its inclusion in the birds' diet may result in a higher deposition of PUFA in poultry tissues.

-There is also evidence suggesting that supplemental Zinc can alleviate negative effects of HS in broiler chickens. For example, plasma zinc was greatly reduced and hepatic zinc was found to be more than four times the amount lost from plasma (Klasing, 1984). Supplemental zinc is used in poultry diets and is reported to be of benefit to laying hens during environmental stress (Sahin and Kucuk, 2003).

-zinc may improve shell quality by assisting the activity of the carbonic anhydrase enzyme, as zinc is a key mineral element of this critical enzyme.

- Interactions among minerals and other nutrients e.g., vitamin E are extensive and may be important in the determination of biological availability of other nutrients. Lipid oxidation causes loss of nutritional and sensory values, as well as the formation of potentially toxic compounds that compromise meat quality and reduce its shelflife. One of such product is malondialdehyde (MDA), which has long been considered as an index of oxidative rancidity. Among all the methods proposed for assessing MDA, the 2-thiobarbituric acid (TBA) has been widely adopted as a sensitive assay method for lipid oxidation in animal tissues.

African Journal of Agricultural Research Vol. 6(12), pp. 2800-2806, 18 June, 2011
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X ©2011 Academic Journals

The effects of dietary fat, vitamin E and zinc supplementation on fatty acid composition and oxidative stability of muscle thigh in broilers under heat stress

R. Vakili* **and A. A. Rashidi**
Department of animal science, Islamic Azad University- Kashmar Branch, Kashmar, Iran.
Accepted 30th May, 2011

The objective of this experiment was to characterize the relationship between dietary fat and antioxidant supplementation on performance, fatty acids profile and lipid oxidation of thigh meat stored under refrigeration in broilers under heat stress. The chicks with a similar body weight were equally assigned to one of the two controlled-environment chambers from 21 to 56 day of age. The birds feddiets as: 1) basal diet supplemented with 5% saturated fatty acid, 2) basal diet supplemented with 5%unsaturated fatty acids (2% canola oil plus 3% fish oil); and 3) The second diet supplemented withantioxidant (100 IU vitamin E and 50 mg/kg zinc); that birds received this 3 diet in two temperature (22and 32°C).Results showed that feed conversion ratio was not influenced by fat type, but on live body weight and feed Intake had significant effect (P<0.05). High environmental temperature showed deleterious effects including: reduction of feed intake, and live body weight and increasing of feed conversion ratio. Proportion of omega-6 to omega-3 (n-6/n-3) of thigh was increased and polyunsaturated fatty acids (PUFA) decreased in heat exposed and tallow-fed chicks. Whereas the proportion of omega-6 to omega-3 (n-6/n-3) of thigh was decreased and polyunsaturated fatty acids (PUFA) increased in chicks fed with canola and fish oils. Fat content and gross energy of thigh in heat exposed and canola and fish oils with antioxidant fed chicks were higher than other treatments.Proportion of omega-6 to omega-3 (n-6/n-3) of thigh was decreased and polyunsaturated fatty acids (PUFA) increased in chicks fed with canola and fish oils. Inclusion of canola and fish oils supplementations increased lipid oxidation of thigh muscle based on TBARA values. Thiobarbituric acid reaction substances (TBARA) values of thigh muscle in chicks fed canola and fish oils reared under heat stress was higher than other treatments. Increasing dietary antioxidants decreased TBARA values of thigh muscle.
Kay words: Broilers, heat stress, dietary fat, fatty acids profile, thigh.

R. vakili, A.A. Rashidi and S.sobhanirad.2010. Effects of dietary fat, Vitamin and zinc supplemention on tibia breaking strength in female broilers under heat stress.*Afican journal of Agricultural Research*.*Vol. 5(23), pp. 3151-3156, 4 December, 2010.*

A.A. Rashidi, y. Gofrani Ivari, A. Khatibyoo and **R. Vakili.2010.**Effects of dietary fat, Vitamin and zink on Immune Respanse and Blood Parameters of Broiler Reared under Heat stress. Medwell *Journals Research journal of poultry Sciensce.* 3(2):32-38

Reza Vakili.2021. Impact of different oil sources on mitigating negative effects of heat stress on performance, thigh proximate composition, fatty acids profile, bone status and immunity of broilers**.** *Journal of Animal nutrition and physiology (under review)***.**