



UNIVERSITI PUTRA MALAYSIA

**ENVIRONMENTAL MANIPULATIONS TO MINIMIZE THERMAL
STRESS IN LAYING HENS IN A HOT HUMID CLIMATE**

IZZELDIN BABIKER ISMAIL

FPV 2001 18



**ENVIRONMENTAL MANIPULATIONS TO MINIMIZE THERMAL
STRESS IN LAYING HENS IN A HOT HUMID CLIMATE**

By

IZZELDIN BABIKER ISMAIL

**Thesis Submitted in Fulfilment of the Requirement for the Degree of Doctor of
Philosophy in the Faculty of Veterinary Medicine
Universiti Putra Malaysia**

March 2001



DEDICATION

**TO MY PARENTS, BROTHERS, SISTERS, MY WIFE HANAN, MY
DAUGHTERS THOEIBA, NOESIBA, NAHLA AND MY SON MOHAMED
FOR THEIR MORAL SUPPORT AND ENCOURAGEMENT**



Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirement for the degree of Doctor of Philosophy

**ENVIRONMENTAL MANIPULATIONS TO MINIMIZE THERMAL
STRESS IN LAYING HENS IN A HOT HUMID CLIMATE**

By

IZZELDIN BABIKER ISMAIL

March 2001

Chairman: Associate Prof. Dr. Kassim Hamid

Faculty: Veterinary Medicine

Three experiments were carried out on laying hens (Hisex Brown) to investigate their performances and to determine the adverse effects of high environmental temperature. The hens were housed in light controlled rooms. Temperature treatment experiment (hot and cold), Light treatments experiment (light and dark) and acclimatization to acute heat (38.5) experiment. Rectal temperature, respiration rate, feed intake, egg production, eggshell quality, blood gas and plasma analysis were reported. The effects of high ambient temperature (35°C) and humidity (68.6%) on the physiology and production performance of laying hens showed a significant ($p < 0.01$) increase in rectal temperature, respiratory rate, blood pH and efficiency of feed conversion. However the partial pressure of carbon dioxide ($p\text{CO}_2$), blood bicarbonate (HCO_3^-) concentration, feed intake, egg production, egg weight, eggshell thickness and albumen quality were significantly decreased

($p < 0.05$). Similarly the blood packed cell volume, haemoglobin, sodium, potassium, calcium and phosphorous concentrations were also significantly decreased ($p < 0.05$).

Synchronization of the dark period with the hot period of the day (T_a ; 35°C , RH; 68.6%) to minimize heat stress in laying hens showed significant increases in feed intake and egg production ($p < 0.01$), eggshell thickness ($p < 0.05$), $p\text{CO}_2$ ($p < 0.01$) and blood HCO_3^- concentration ($p < 0.05$). However, significant decreases in the efficiency of feed conversion ($p < 0.05$), egg weight ($p < 0.01$) and rectal temperature ($p < 0.05$) were recorded. The blood pH, plasma calcium and phosphorous concentrations of the dark-treated and the light-treated groups were not significantly different. However, plasma cholesterol concentration of the light-treated group was significantly higher ($p < 0.01$) than the dark-treated group when exposed to high ambient temperature. The heart was significantly ($p < 0.05$) heavier and enlarged in the birds kept in the light during the high environmental temperature of 35°C .

Acclimatization studies on the dark-treated and light-treated laying hens to acute heat of 38.5°C increases the rectal temperature to 43.9°C and 44.1°C respectively on the first day of acute heat exposure. On the following days the rectal temperature gradually decreased reaching the lowest value on day three for the dark-treated and day four for the light-treated group. Similarly, a significant increase in shank and comb temperatures were observed reflecting the body heat load,

stimulating vasodilatation in an attempt to cool the body by heat dissipation. The blood pH of the dark-treated and the control groups increased to 7.59 and 7.58, respectively. The $p\text{CO}_2$ and HCO_3^- concentrations were significantly ($P < 0.01$) increased in the dark-treated group. Plasma cholesterol concentration was significantly ($p < 0.01$) increased during light and decreased during dark treatments. High temperatures during light or darkness did not affect plasma calcium or phosphorous concentration. The result concluded that the efficiency of feed conversion was improved under heat stress. However, egg production and feed intake were decreased. Dark treatment improved acclimatization to acute heat. Exposure to heat during the light increased plasma cholesterol and heart weight.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**MANIPULASI PERSEKITARAN UNTUK MEMINIMUMKAN TEKANAN
TERMAL TERHADAP AYAM PENELUR DALAM
IKLIM PANAS**

Oleh

IZZELDIN BABIKER ISMAIL

Mac 2001

Pengerusi: Prof. Madya Dr. Kassim Hamid

Fakulti : Perubatan Veterinar

Tiga kajian telah dijalankan terhadap ayam penelur (Hisex Brown) untuk menyelidik prestasinya dan untuk menentukan kesan buruk suhu persekitaran tinggi. Kesan suhu ambien tinggi (35°C) dan kelembapan (68.6%) terhadap fisiologi dan prestasi penghasilan ayam penelur menunjukkan peningkatan bererti ($p < 0.01$) bagi suhu rektum, kadar penafasan, pH darah dan kecekapan penukaran makanan. Walau bagaimanapun tekanan separa karbon dioksida ($p\text{CO}_2$), kepekatan bikarbonat (HCO_3^-) darah, pengambilan makanan, penghasilan telur, berat telur, ketebalan cangkerang telur dan mutu albumen menurun secara bererti ($p < 0.05$). Begitu juga dengan isipadu sel padat darah, kepekatan hemoglobin, natrium, kalium, kalsium dan fosforus, turut turun secara bererti ($p < 0.05$).

Penyelarasan tempoh gelap dengan suhu panas (T_a ; 35°C , RH; 68.6%) pada sesuatu hari untuk meminimumkan tekanan haba dalam ayam penelur menunjukkan peningkatan bererti dalam pengambilan makanan dan penghasilan telur ($p < 0.01$), ketebalan cengkerang telur ($P < 0.05$), $p\text{CO}_2$ ($p < 0.01$) dan kepekatan HCO_3^- darah ($p < 0.05$). Walau bagaimanapun, penurunan bererti dalam kecekapan penukaran makanan ($p < 0.05$), berat telur ($p < 0.01$), dan suhu rektum ($p < 0.05$) telah direkodkan. Bagi pH darah, kepekatan kalsium dan fosforus plasma dalam kumpulan rawatan gelap dan rawatan cahaya tidak berbeza secara bererti. Walau bagaimanapun, kepekatan kolesterol plasma dalam kumpulan rawatan cahaya adalah lebih tinggi dan bererti ($p < 0.01$) daripada kumpulan rawatan cahaya apabila didedahkan kepada suhu ambien tinggi. Berat jantung adalah tererti ($p < 0.05$) tingginya dan membesar dalam kumpulan ayam rawatan cahaya semasa berada pada suhu persekitaran tinggi, 35°C .

Penyesuaian iklim ayam rawatan gelap dan rawatan cahaya kepada haba 38.5°C menunjukkan peningkatan suhu rektum masing-masing kepada 43.9°C dan 44.1°C pada hari pertama pendedahan haba yang meruncing. Pada hari-hari berikutan, suhu rektum beransur turun mencapai nilai terendah pada hari ketiga untuk kumpulan rawatan gelap dan hari keempat untuk kumpulan perlakuan cahaya. Apa yang juga dicerap ialah peningkatan bererti bagi suhu betis dan balung yang mencerminkan beban haba badan, dan ini merangsang pemvasodilatan dalam usaha menyejukkan badan dengan menghilangkan haba. Bagi pH darah kumpulan rawatan

gelap dan kawalan, masing-masing meningkat kepada 7.59 dan 7.58. $p\text{CO}_2$ dan kepekatan HCO_3^- meningkat ($p < 0.01$) dengan bererti dalam kumpulan rawatan gelap. Kepekatan kolesterol plasma meningkat ($p < 0.01$) dengan bererti dalam tempoh rawatan cahaya dan menurun dalam tempoh rawatan gelap. Suhu tinggi dibawah cahaya dan dalam kegelapan tidak memberi sebarang kesan terhadap kepekatan kalsium atau fosforus. Hasil kajian menunjukkan walaupun suhu ambien tinggi membesei kesan buruk terhadap suhu badan dan penghasilan telur, ia dapat meningkatkan kecekapan penukaran makanan masih meningkat. Kegelapan pada masa tekanan haba meminimumkan kesan buruk walaupun berat telur menurun. Rawatan gelap meningkatkan penyesuaiikliman terhadap haba yang meruncing, walau bagaimanapun cahaya dan suhu ambien tinggi secara gabungan meningkatkan kepekatan kolesterol plasma dan berat jantung.

ACKNOWLEDGEMENTS

First, my praise to Almighty Allah for giving me the power and will to complete this study and Peace be upon his final Prophet and Messenger Mohammed.

My sincere appreciation to my supervisory committee, who were involved in my training towards obtaining this degree. I have the highest regard for their professional courtesy. I wish to express my profound gratitude and sincere appreciation to Associate Professor Dr. Kassim Hamid, Chairman of my Supervisory Committee, for his kind help, guidance, criticisms, continuous encouragement and invaluable assistance during the course of the study. I am much indebted and grateful to Associate Professor Dr. Rasedee Abdullah and Dr. Ismail Idris, members of my Supervisory Committee, for their encouragement, constructive discussion, advice, comments and suggestions.

I wish to express my sincere gratitude to the Dean of the Faculty of Veterinary Medicine, University Putra Malaysia for allowing me to use the facilities of his laboratories and unlimited assistance during the course of this study. I would also like to thank the staff members of Physiology and Clinical Pathology Laboratories in particular Dr. Goh Yong Meng, Mrs. Zainab Nasri, Mrs. Rosmawati Mohd. Hanipah, Mr. Johari Ripin, Mr. Kufli Che Noor, Dr. Ragavan Koran, Mr.

Mohd. Halmi Othman and Mr. Fauzi Othman Che Yusuf for their invaluable assistance during my study.

I am also thankful to Associate Professor Dr. Zulkifli Idrus, Associate Professor Ramlah Hamid, Mr. Mazlan Hamzah, Mr. M. Ponnusamy and Hj. Shahril Hassan from Faculty of Agriculture, Universiti Putra Malaysia for their collaboration.

It is worth to mention my friends and colleagues from whom I received direct and indirect support I would like to thank Mr. Mustafa Fadil, Dr. Wihandoyo, Mr. Elwaleed Awad Khidir, Dr. Isam Elgali, Dr. Omar Arabi, Dr. Mohammed Ali, Mr. Mahmoud Onsa, Dr. Mahgoub Osman, Dr. Musadag Elawad, Dr. Hatim Elsheik, Dr. Ibrahim Omar, Dr. Mohammed Osman Bushara, Sheikh Mohtady and Mr. Asaad for their companionship support and concern.

I am most grateful to the University of Khartoum (Sudan) and IRPA Grant (No. 01-02-04-226), Ministry of Science and Technology (Malaysia) for the financial support. Finally, I wish to express my deepest appreciation to the staff of the Graduate School for all kinds of assistance and facilities provided to us as international students that make our life in UPM campus at ease.



This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

KAMIS AWANG, Ph.D.,
Associate Professor,
Dean of Graduate School,
University Putra Malaysia

Date:



TABLE OF CONTENTS

		Page
DEDICATION.....		2
ABSTRACT.....		3
ABSTRAK.....		6
ACKNOWLEDGMENTS.....		9
APPROVAL.....		11
DECLARATION		13
LIST OF TABLES.....		18
LIST OF FIGURES.....		20
LIST OF ABBREVIATIONS.....		23
 CHAPTER		
I	INTRODUCTION.....	25
II	LITERATURE REVIEW	31
	Heat Stress.....	31
	Heat Balance and Thermoregulation	33
	Environmental Zones.....	35
	Thermoneutrality.....	37
	Effect of Environment Temperature on Performance of Laying Hens	40
	Effect of Temperature on Feed and Energy Intake.....	40
	Effect of Temperature on Egg Production and Egg Quality	44
	Effect of Temperature on Blood Parameters	51
	Effect of Temperature on Acid-Base Balance.....	51
	Effect of Temperature on Plasma Calcium, Phosphorous and Electrolyte	54
	Effect of Temperature on Plasma Cholesterol.....	56
	Effect of Temperature on Immune Response.....	56
	Effect of Light on Performance of Laying Hen	58
	Effect of Light on Behavior of Laying Hen	59
	Effect of Light Intensity on Laying Hen	61
	Effect of Light on Feed Intake and Heat Production.....	62
	Effect of Light on Oviposition and Egg Production.....	64
	Photorefractoriness	66
	Acclimatization of Laying Hen to Hot Environment.....	68
III	GENERAL MATERIALS AND METHODS.....	73
	Location and Housing	73
	Experimental Birds	74

Experimental Feed.....	74
Temperature and Humidity Measurement.....	74
Blood Gas Electrolyte Analyzers.....	75
Blood Biochemistry	75
Feed Intake (g)	76
Egg Production and Egg Quality	77
Egg Weight (g)	77
Haugh Unit (Albumin Quality).....	77
Eggshell Thickness	78
Room Temperature and Humidity.....	79
Rectal Temperature (Tr. °C).....	79
Respiratory Rate	79
Blood Sampling and Analysis.....	80
Packed Cell Volume (PCV%).....	80
Blood Gas Analysis.....	80
Electrolyte Analysis.....	81
Plasma Biochemical Analysis.....	81
Plasma Calcium	82
Plasma Phosphorous	84
Plasma Cholesterol	85
Statistical Analysis.....	86
IV THE EFFECT OF HIGH AMBIENT TEMPERATURE ON THE PERFORMANCE OF LAYERS	87
Introduction	87
Materials and Methods.....	90
Birds	90
Housing.....	90
Feed.....	91
Parameters Measured.....	91
Results	92
Effect of Room Temperature on Rectal Temperature and Respiratory Rate	92
Effect of Room Temperature on Feed Intake and Efficiency of Feed Conversion	96
Effect of Room Temperature on Egg Production and Egg Weight	99
Effect of Room Temperature on Eggshell Thickness and Albumen Quality (Haugh Unit)	102
Effect of Room Temperature on Packed Cell Volume and Haemoglobin Concentration	103
Effect of Room Temperature on Blood Acid–base Balance and Blood Gas	103

	Effect of Room Temperature on Blood Calcium Phosphorous and Electrolyte	105
	Discussion.....	106
V	EFFECT OF THE LIGHT AND DARK PERIOD DURING THE HOT PERIOD OF THE DAY ON THE PERFORMANCE OF LAYING HENS	113
	Introduction.....	113
	Materials and Methods.....	119
	Birds.....	119
	Housing and Photoschedule.....	119
	Feed.....	120
	Parameters measured.....	120
	Results	121
	Effect of Dark and Light Treatment on Rectal Temperature	121
	Effect of Dark and Light Treatments on Feed Intake and Feed Conversion Efficiency of Laying Hens	122
	Effect of Dark and Light Treatment on Egg Production and Egg Quality	126
	Effect of Dark and Light Treatment on Acid Base Balance of Laying Hens	129
	Effect of Dark and Light Treatment on Blood Biochemistry of Laying Hens	130
	Effect of Dark and Light Treatment on Body and Visceral Organs Weight of Laying Hens	131
	Discussion.....	132
VI	EFFECT OF THE LIGHT AND DARK PERIOD DURING THE HOT PERIOD OF THE DAY ON ACCLIMATIZATION OF LAYING HENS TO ACUTE HEAT EXPOSURE.....	139
	Introduction.....	139
	Materials and Methods.....	141
	Birds	141
	Feed	141
	Housing and Photoschedule	142
	Environmental Chamber.....	142
	Acute Heat Treatment.....	143
	Temperature Measurements.....	143
	Blood Sampling and Analysis.....	144
	Results	144
	Effect of Dark and Light on Rectal Temperature of Laying Hens During Acclimatization to Acute Heat	144

	Effect of Dark and Light on Comb and Shank Temperature of Laying Hens during Acclimatization to Acute Heat	150
	Effect of Dark and Light on Acid-Base Balance and Blood Gas during Acclimatization.....	154
	Effect of Dark and Light on Blood Biochemistry of Laying Hens during Acclimatization	159
	Discussion.....	164
VII	GENERAL DISCUSSION	169
VIII	CONCLUSIONS.....	182
	Future Prospect and Suggestions.....	
	BIBLIOGRAPHY	184
	APPENDIX	212
	A	213
	B.....	221
	C.....	224
	D.....	229
	E.....	231
	BIODATA OF THE AUTHOR	236

LIST OF TABLES

Table		Page
1	The effect of room temperature on body temperature and respiratory rate of laying hens	93
2	The effect of room temperature on production performance of laying hens	102
3	The effect of hot and cold room temperature on blood hemoglobin and packed cell volume of laying hens	103
4	The effect of room temperature on acid-base and blood gas of laying hens	104
5	The effect of room temperature on blood plasma electrolyte, calcium, phosphorous and cholesterol of laying hens	105
6	The effect of dark and light treatments on performance of laying hens exposed to high ambient temperature (35 ⁰ C).....	126
7	The effect of dark and light treatments on body temperature and blood gas parameters in laying hens at high ambient temperature	130
8	The effect of dark and light treatments on blood biochemistry (cholesterol, calcium and phosphorous) in laying hens at high ambient temperature	131
9	The effect of dark and light treatments on visceral weight of laying hens at high ambient temperature	132
10	The effect of acute heat (38.5±0.5 ⁰ C) on rectal, comb and shank temperatures of laying hens during light and dark periods	154
11	Blood gas analysis in laying hens exposed to acute heat (38.5±0.5 ⁰ C) during light and dark periods	160

12	Plasma cholesterol, calcium and phosphorous in laying hens exposed to acute heat ($38.5\pm 0.5^{\circ}\text{C}$) during light and dark periods	160
----	--	-----

LIST OF FIGURES

Figure		Page
1	Generalized schematic diagram illustrating body temperature (T_b) and partitioning energy exchange through a wide range of ambient temperature (T_a)	36
2	Average rectal temperature of Laying Hens at Maximum Temperature in the Hot Room (35 °C) and in the Cold Room (20 °C)	94
3	Respiratory rate of Laying Hens at Maximum Temperature in the Hot Room (35 °C) and in the Cold Room (20 °C)	95
4	Mean Weekly Feed Intake of Laying Hens in the Hot Room (35 °C) and in the Cold Room (20 °C)	97
5	Mean Weekly Feed Conversion Ratio of Hens in the Hot Room (35 °C) and in the Cold Room (20 °C)	98
6	Mean Weekly Egg Production of Laying Hens in the Hot Room (35 °C) and in the Cold Room (20 °C)	100
7	Mean Weekly Egg Weight of Laying Hens in the Hot Room (35 °C) and in the Cold Room (20 °C)	101
8	Diagrammatic Representation of the Photoschedule of Dark Treated and the Light Treated Hens (control) throughout the 24 hrs Light-Dark cycle	120
9	Effect of Dark (D) and Light (L) Treatments on Rectal Temperature of Laying Hens at High Ambient Temperature (35 °C)	123
10	Effect of Dark (D) and Light (L) Treatments on Feed Intake of Laying Hens at High Ambient Temperature (35 °C)	124
11	Effect of Dark (D) and Light (L) Treatments on Feed Conversion Ratio of Laying Hens at High Ambient Temperature (35 °C)	125

12	Effect of Dark (D) and Light (L) Treatments on Egg Production of Laying Hens at High Ambient Temperature (35°C)	127
13	Effect of Dark (D) and Light (L) Treatments on Egg Weight of Laying Hens at High Ambient Temperature (35 °C)	128
14	Rectal (Tr) and Comb (Tcom) Temperatures on the first day of 3 hours of acute heat exposure during the Dark (D) and the Light (L) period	146
15	Rectal (Tr) and Shank (Tsh) Temperatures on the first day of 3 hours of acute heat exposure during the Dark (D) and the Light (L) period	147
16	Rectal (Tr) and Comb (Tcom) Temperatures on the second day of 3 hours of acute heat exposure during the Dark (D) and the Light (L) period	148
17	Rectal (Tr) and Comb (Tcom) Temperatures on the seventh day of 3 hours of acute heat exposure during the Dark (D) and the Light (L) period	149
18	Mean Rectal Temperature of Laying Hens Exposed to Acute Heat (35 °C) at the 3rd hour daily for 7 Consecutive days during the Light (L) and the Dark (D) periods	151
19	Mean Rectal (Tr) and Comb (Tcom) Temperatures of Laying Hens Exposed to Acute Heat (35 °C) at the 3rd hour daily for 7 Consecutive days during the Light (L) and the Dark (D) periods	152
20	Mean Rectal (Tr) and Shank (Tsh) Temperatures of Laying Hens Exposed to Acute Heat (35 °C) at the 3rd hour daily for 7 Consecutive days during the Light (L) and the Dark (D) periods	153
21	Blood pH of Laying Hens Exposed to Acute Heat (38.5 °C) at the 2nd hour daily for 7 Consecutive days during Light (L) and Dark (D) periods	156
22	Blood pCO ₂ of Laying Hens Exposed to Acute Heat (38.5 °C) at the 2 nd hour daily for 7 Consecutive days during Light (L) and Dark (D) periods	157

23	Blood HCO ₃ of Laying Hens Exposed to Acute Heat (38.5 °C) at the 2nd hour daily for 7 Consecutive days during Light (L) and Dark (D) periods	158
24	Blood Cholesterol Concentration of Laying Hens Exposed to Acute Heat (38.5 °C) at the 2nd hour daily for 7 Consecutive days during light (L) and dark (D) period	161
25	Plasma Calcium of Laying Hens Exposed to Acute Heat (38.5 °C) at the 2nd hour daily for 7 Consecutive days during light (L) and dark (D) periods	162
26	Plasma Phosphorous of Laying Hens Exposed to Acute Heat (38.5 °C) at the 2nd hour daily for 7 Consecutive days during Light (L) and Dark (D) period	163

LIST OF ABBREVIATIONS

AH	Albumen Height
ALF	<i>Ad libitum</i> Feeding
<i>ATPase</i>	<i>Adenosine Triphosphatase</i>
ACTH	Adrenocorticotropin
BL	Blue Light
BMLP	Biomittent Lighting Program
BW	Body weight
°C	Degree Celcius
C	Rate of convective heat transfer
CaBP	Calcium Binding Protein
CBF	Capillary Blood Flow
CE	Cholesterol Esterase
CO ₂	Carbon Dioxide
ChOD	Cholesterol Oxidase
CHOL	Cholesterol
CL	Continuous light
cm	Centimeter
CS	Corticosterone
CSF	Cerebrospinal Fluid
Cp	Specific Heat Of The Body Mass
D	Dark
dt	Change in Time
DTb	Change in Body temperature
EHL	Evaporative Heat Loss
g	Gram
GL	Green Light
GLU	Glucose
HCO ₃	Bicarbonate
HDL	High-density lipoprotein
H/L	Heterophil/lymphocyte ratio
h	hour time
IL	Intermittent Light
K	Rate of Conductive Heat Transfer
KCL	Potassium Chloride
L	Light
l	Liter
MHP	Rate of Metabolisable Heat Production
min	Minute
mm	Millimeter
mmol	Millimole
m/s	meter per second
NaCl	Sodium Chloride

NaHCO ₃	Sodium Bicarbonate
PCV	Packed Cell Volume
PTU	Propylthiouracil
pO ₂	Partial Pressure of Oxygen
pCO ₂	Partial Pressure of Carbon Dioxide
pH	Hydrogen Ions Concentration
R	Rate of radiant heat transfer
RH	Relative Humidity
RL	Red Light
RR	Respiratory Rate
SHL	Sensible Heat Loss
T	Time
T ₃	Triiodothyronine
T ₄	Thyroxine
T _a	Ambient Temperature
T _b	Body Temperature
THb	Total Haemoglobin
TNZ	Thermoneutral Zone
TP	Total protein
TRI	Triglycerides
TU	Thiouracil
Tr	Rectal Temperature
ZLTE	Zone of Least Thermoregulatory Effort
ZMM	Zone of Minimum Metabolism
THb	Total Haemoglobin
T _{com}	Comb Temperature
T _{cu}	Upper Critical Temperature
T _{sh}	Shank Temperature
WL	White Light
VE	Ventilation