

FEEDING PROGRAMS COULD IMPROVE GROWTH PERFORMANCE AND PHYSIOLOGICAL STATUS OF GROWING NEW ZEALAND WHITE RABBITS DURING HOT SUMMER SEASON OF EGYPT.

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ABSTRACT: *Effects of feeding program (times and quantities) on some growth performance, blood biochemistry, carcass traits and behavioral patterns of male New Zealand White rabbits (NZW) during summer season were investigated. Weaned NZW rabbits (80 bucks) were similarly randomly (735 ± 4.7 g) assigned into five experimental groups. Rabbits of the first group were fed ad libitum (control; C). The second group (T1) was fed 75% of diet at the morning and 25% of diet at the night (7 PM); the third group (T2) was fed 50% of diet at the morning and 50% of diet at the night; the fourth group (T3) was fed 25% of diet at the morning and 75% of diet at the night; the fifth one (T4) was fed 100% of diet at the night. Rabbits of T3 group showed the heaviest body weight and body weight gain and the best feed conversion ratio during 14-16 weeks of age. Groups of T3 and T4 showed the highest percentage of dressed carcass and the lowest abdominal fat. Rabbits of T3 had the lowest activity of alanine aminotransferase (AST), the lowest value of rectal temperature and the highest glucose concentration. **Conclusively**, feeding during the night was preferable in rabbit farms due to its useful impacts on growth, under heat stress of summer months of Egypt.*

Keywords: Rabbit, feeding program; heat stress; growth; blood

INTRODUCTION

Heat stress affects negatively growth rate, feed conversion ratio (FCR) and blood parameters (Abdel-Monem *et al.* , 2007; Daader *et al.* , 2016; Hassan *et al.*,

2016; Szendrő *et al.*, 2018; Ferraz *et al.*, 2019; Farghly *et al.*, 2020; Awad *et al.*, 2021). The optimal range of temperature and relative humidity for keeping rabbits is 15-25 °C, and 60-65 %, respectively (Abdel-Monem *et al.*, 2009). Several attempts were carried out to alleviate the deleterious effects of heat stress (Jimoh and Ewuola, 2016 & 2018; Farghly *et al.*, 2020; Awad *et al.*, 2021).

Feeding programs (times and quantities) during the day has attracted several investigators (Bergaoui *et al.*, 2008; Gidenne *et al.*, 2012; Sena *et al.*, 2015, Peris and Abd El-Latif, 2021) in attempts to ameliorate the deleterious impacts of heat stress and to improve the biological execution. Rabbits prefer to feed nocturnally and consume 60-70% of the feed at night (Abdel-Monem *et al.* 2007 and 2009). To control feed consumption (FC) during growth, the most careful strategy is to give a determined volume of diet a day, which could be given at once or as several meals (Gidenne *et al.*, 2012). There are 3 peak periods (03:00-06:00, 15:00-18:00 and 18:21 h) of feed consumption in rabbits; (Ogbu *et al.*, 2014). Recent studies, Abou-Kassem *et al.*, (2021) and Peris and Abd El-Latif (2021) found that the feed restriction system improved feed utilization by giving the best values of FCR in growing rabbits.

Influence of different feeding times and quantities on the growth performance and the physiological status of growing rabbits during a day under heat stress are not well investigated.

Therefore, the current investigation was carried out to examine the potential of improving the growth performance and the physiological status of growing NZW rabbits under the high temperature of summer conditions by utilizing different feeding programs (times and quantities) during a day in summer season.

MATERIALS AND METHODS

The present study was implemented at the Rabbitry Farm, Faculty of Agriculture, Assiut University, Egypt.

Rabbits and experimental design

Eighty bucks of weaned NZW rabbits (average of body weight; 735 ± 4.7 g), 6 weeks of age, were randomly assigned into five groups (16 rabbit per each group) in a completely randomized design experiment during summer months (June-August).

The first group was fed *ad libitum* (control; C). The second group (T₁) was fed a program (75% of diet at the morning and 25% of diet at the night ,7 PM); the third group (T₂) was fed a program (50% of diet at the morning and 50% of diet at the night); the fourth group (T₃) was fed a program (25% of diet

at the morning and 75% of diet at the night); the fifth one (T₄) was fed a program (100% of diet at the night).

Rabbits (80 bucks) were kept in wire galvanized cages (50L× 55W× 40H cm), which were provided with manual feeders and automatic nipple drinkers. Rabbits were fed a pelleted basal diet contained 2670 ME/kcal, 18.25% CP and 11.17% CF (NRC 1994). All rabbits were raised in a semi-closed house and subjected to the same managerial, hygienic and environmental conditions. Intensity of light was recorded (25-30 lux) through incandescent bulbs. Ambient temperature (C°) and relative humidity (%) were recorded and temperature-humidity index (THI) was calculated (Table 1) according to Marai *et al.* (2001) as follows:

$$THI = db C^{\circ} - \{(0.31-0.31RH)(db C^{\circ}-14)\},$$

Where db C° represents dry bulb temperature in Celsius and RH = Relative humidity %, values of THI were classified as follows; < 22.2 = Absence of heat stress, 22.2 to <23.2 = Moderate heat stress, 23.3 to <25.5 = Severe heat stress, and ≥ 25.5 = Very severe heat stress.

Table 1. Means of indoor temperature and humidity values of semi-closed system house

Months	Temperature [C°]			Humidity [%]			THI		
	Max.	Min	Av.	Max.	Min.	Av.	Max.	Min.	Av.
June	33.88	24.64	29.26	59.85	42.23	51.04	31.46	22.81	27.00
Julie	35.00	27.11	31.06	62.00	44.52	53.26	32.57	24.92	28.64
August	35.92	26.86	31.39	61.22	43.00	52.11	33.33	24.66	28.87
Overall mean	34.93	26.20	30.57	61.02	43.25	52.14	32.45	24.13	28.17

Max.= Maximum, Min.= Minimum and Av.= Average

Studied parameters

Body weight (BW) and FC of each rabbit were measured at 6 weeks of the age, and bi-weekly up to 16 weeks. Body weight gain (BWG) and FCR (g feed/ g gain) were obtained bi-weekly. Rectal temperature (C°) was recorded, on a weekly basis at 1400 h. At 16 weeks of age, 5 animals per group were randomly chosen and slaughtered (Nofal *et al.*, 1995). Dressed carcass weight and weights of edible parts (liver, heart and kidneys) were recorded. Dressing output as a percentage was obtained by dividing the dressed carcass weight by pre-slaughter weight. Blood samples were collected during slaughter. Plasma total protein, albumin, cholesterol, total lipids and glucose and Aspartate aminotransferase (AST) and Alanine aminotransferase (ALT) activities were measured using kits (Peris and Abd El-Latif, 2021). Globulin was obtained by subtracting and albumin: globulin ratio was calculated. Mortality and morbidity were recorded daily. Health risk was considered as the total of morbidity and mortality.

The behavioral observations (Resting or sleeping, lying at any position and sitting; locomotion; grooming; investigatory as rubbing, licking, gnawing, smelling; aggressive as biting, fighting and chasing each other) were carried out (Paul and Patrick, 2007). All rabbits were monitored from 1200 to 1400 h for 3 days a week to get 3 times of monitoring intervals for each group (10 minutes at each time).

Statistical analysis

Data obtained from the experiment were subjected to One-Way analysis of variance according to Snedecor and Cochran (1982), using the GLM (General Linear Model) procedures of SAS software (SAS 1996). The statistical model used was as follows:

$$Y_{ij} = \mu + T_i + e_{ij},$$

Where Y_{ij} is an observation, μ is the overall mean, T_i is the effect of feeding program, and e_{ij} is the experimental random error.

The variations among averages of the different experimental groups were calculated (Duncan, 1955).

RESULTS AND DISCUSSION

Temperature–humidity index:

Temperature–humidity index (THI) values ranged between 27.00 and 28.87, indicating exposure of NZW rabbits to very severe heat stress (Table 1). Using a set of two or more climatic elements is necessary to ideally measure heat stress (Daader *et al.*, 2016). The US-National Weather Service uses the THI index to help animal producers of the expected heat severity (Hahn *et al.* 2009; Jimoh and Ewuola, 2016).

Some growth performance traits

There were significant variations in BW at 14 and 16 weeks of age and during 12-14 and 14-16 weeks of age for BWG (Table 2). Rabbits of T3 group showed significantly ($P < 0.05$) the heaviest averages of BW and BWG. Favorable effects were found due to changing feeding program (times and quantities) over the day on growth performance. Growing rabbits utilize feed during the coolest periods of the day during the hot weather (Ojebiyi *et al.*, 2015). The lighter BW and BWG of the control and T1 groups might attribute to the poorer health status in comparison with the others. Tůmová *et al.* (2003) found similar results.

There were significant variations in FC at 8-10 weeks of age during and 12-14 and 14-16 weeks of age in FCR. FCR of rabbits of T3 group was significantly improved ($P < 0.05$) as shown in Table 2. The majority of the

Table 2. Effect of feeding program on growth performance of New Zealand White rabbits male growing rabbits

Traits	Age (wks)	Treatment groups					SEM	P value
		C	T ₁	T ₂	T ₃	T ₄		
Body weight (g)	6	743.5	727.2	742.1	725.9	734.8	4.7	0.674
	8	983.2	983.8	982.2	987.7	983.9	6.6	0.999
	10	1259.3	1265.0	1275.6	1279.6	1293.6	9.6	0.828
	12	1636.4	1640.0	1678.2	1688.1	1707.4	10.4	0.133
	14	1939.1 ^b	1939.5 ^b	2004.2 ^{ab}	2031.1 ^a	1983.3 ^{ab}	10.3	0.012
	16	2157.3 ^d	2188.7 ^{cd}	2243.1 ^{bc}	2343.1 ^a	2270.6 ^b	13.1	<.0001
Body weight gain (g/rabbit/day)	6-8	17.1	18.3	17.1	18.7	17.8	0.39	0.637
	8-10	19.7	20.1	20.9	20.9	22.1	0.49	0.599
	10-12	26.9	26.7	28.7	29.1	29.6	0.49	0.228
	12-14	21.6 ^{ab}	21.4 ^{ab}	23.3 ^a	24.5 ^a	19.7 ^b	0.51	0.026
	14-16	15.6 ^c	17.8 ^{bc}	17.1 ^c	22.3 ^a	20.5 ^{ab}	0.54	0.0002
	Mean	20.2^d	20.8^{cd}	21.4^{bc}	23.1^a	21.9^b	0.18	<.0001
Feed consumption (g/rabbit/day)	6-8	60.0	60.6	60.2	59.9	59.9	0.28	0.9424
	8-10	69.3 ^{ab}	67.5 ^b	71.5 ^a	68.9 ^{ab}	68.5 ^{ab}	0.49	0.0110
	10-12	91.6	90.4	93.6	90.5	93.1	0.59	0.279
	12-14	103.2	102.3	103.7	103.3	101.6	0.62	0.832
	14-16	107.3	107.7	109.0	109.6	108.2	0.57	0.709
	Mean	86.3	85.6	87.6	86.5	86.3	0.39	0.641
Feed conversion ratio (g feed/g gain)	6-8	3.7	3.4	3.6	3.3	3.5	0.08	0.543
	8-10	3.80	3.56	3.5	3.5	3.19	0.11	0.544
	10-12	3.44	3.44	3.3	3.2	3.22	0.06	0.542
	12-14	4.9 ^{ab}	5.1 ^{ab}	4.8 ^{ab}	4.4 ^b	5.29 ^a	0.11	0.054
	14-16	7.2 ^a	6.2 ^{ab}	6.99 ^a	5.1 ^b	5.65 ^b	0.20	0.003
	Mean	4.60^a	4.33^{ab}	4.40^{ab}	3.91^c	4.17^{bc}	0.05	0.0003

^a and ^b Means within each row for each division with no common superscripts are significantly different ($P \leq 0.05$).

lowering in FC and FCR in the hot season is attributed to the decrease in maintenance needs (Morêki, 2008). In this work, FC of rabbits remains below or similar to that of the control group and FCR was improved in rabbits of T3 by 21%. The similar quantities of FC might be due to that the rabbits cannot over-eat (Gidenne *et al.*, 2012) and adapted to the restriction applied (Gidenne and Lebas 2006) and weak of feed storage capacity of their stomach (Ogbu *et al.*, 2014). Feed restriction improves FCR (Dalle Zotte *et al.*, 2005). Rabbits consume most of feed during 03:00-06:00, 15:00-18:00 and 18:21 h (Ogbu *et al.*, 2014). Rabbits fed during the different periods in this work may utilize these periods and gave similar values of FC. The resemblance in FC with the

control group may indicate that rabbits can eat at different times a day according to the availability of the feed (Ogbu *et al.* 2014) and the physiological status of the rabbits (Daader *et al.*, 2016). Diet could be consumed during 16 h for an 85% FC and during 10 h for a 70% FC during summer season (Bergaoui *et al.*, 2008). Feeding growing rabbits for only 10 h a day decreased FC by 20%, while night feeding decreased FC by 10% and the daily gain to 5% (Sena *et al.*, 2015). Ojebiyi *et al.* (2015) also observed that BW of rabbits of night feeding exceeded those diurnally fed.

Some carcass traits:

Dressed carcass and abdominal fat percentages were significantly ($P < 0.05$) differed (Table 3). Feeding program (times and quantities) did not impact the other carcass traits. Groups of T3 and T4 had the highest percentage of dressed carcass and the lowest abdominal fat (Table 3). When implementing alternative feeding programs, carcass traits are major elements to consider (Tůmová *et al.*, 2006). Climate could impact carcasses in two methods; firstly, through the immediate influences on organs and muscle metabolism during heat stress and those can continue after slaughter. Secondly, the differences in management processes in reaction to risks that originate from climate change could indirectly lead to differences in the carcass (Dalle Zotte *et al.*, 2005). The present results indicate that feeding regimes seemed not to change edible parts. Ojebiyi *et al.* (2015) concluded that rabbits fed nocturnally had the highest carcass percentage in comparison with animals fed *ad libitum* or diurnally. Dressed carcass was higher in restricted rabbits than those of the *ad libitum* (Tůmová *et al.*, 2006). Abdominal fat percentage was decreased due to the length of feeding time restriction (Sena *et al.* 2015). Also, Peris and Abd El-Latif (2021) observed that kidney fat in restricted rabbits decreased significantly compared with rabbits fed *ad libitum*. Insignificant differences in carcass traits of growing rabbits were also observed by Tůmová *et al.* (2003) and Peris and Abd El-Latif (2021).

Some blood biochemical parameters

Non-significant variations were detected in the most of blood parameters, except in ALT and glucose concentrations (Table 4). Rabbits of T3 had significantly ($P < 0.05$) the lowest activity of ALT and the highest glucose concentration. Blood parameters are significant for estimation of the health status and the level of metabolism. The current concentrations of blood parameters were within the physiological ranges reported by Özkan *et al.* (2012). The present results indicate that the feeding times did not influence formation and transfer of blood proteins and protein catabolism. Blood glucose is a commensurable indicator that can be used to assess the acuteness of the

Table 3. Effect of feeding program on dressing and edible percentages of New Zealand White rabbits male growing rabbits.

Traits	Treatment groups					SEM	P value
	C	T ₁	T ₂	T ₃	T ₄		
Dressed carcass %	58.69 ^{ab}	57.33 ^b	58.71 ^{ab}	58.86 ^{ab}	59.47 ^a	0.423	0.0365
Heart, %	0.412	0.402	0.423	0.404	0.413	0.001	0.5062
Liver, %	3.83	4.95	3.91	4.22	4.10	0.062	0.0996
Kidney, %	0.712	0.691	0.753	0.682	0.691	0.083	0.4562
Whole fat, %	3.02 ^a	2.98 ^{ab}	2.92 ^{ab}	2.53 ^b	2.84 ^{ab}	0.091	0.0195

^{a and b} Means within each row for each division with no common superscripts are significantly different ($P \leq 0.05$).

Table 4. Effect of feeding program on some biochemical blood parameters of New Zealand White rabbits male growing rabbits

Traits	Treatment groups					SEM	P value
	C	T ₁	T ₂	T ₃	T ₄		
Total proteins (mg/dl)	7.02	6.94	7.00	6.86	7.21	0.09	0.6352
Globulin (mg/dl)	3.02	2.98	2.92	3.00	3.10	0.04	0.2631
Albumin (mg/dl)	4.00	3.96	4.08	3.86	4.11	0.05	0.2454
A: G ratio	1.32	1.33	1.40	1.29	1.33	0.04	0.3462
AST U/I	33.55	32.67	31.12	31.01	30.87	0.92	0.3263
ALT U/I	18.32 ^{ab}	18.81 ^a	18.10 ^{ab}	16.19 ^b	16.22 ^b	0.36	0.0123
Glucose (mg/dl)	16.11 ^{ab}	13.92 ^b	14.33 ^b	16.88 ^a	15.80 ^{ab}	0.42	0.0502
Cortisol (ng/ml)	12.93	13.11	11.80	10.73	11.00	1.11	0.3546

^{a and b} Means within each row for each division with no common superscripts are significantly different ($P \leq 0.05$).

rabbit's status and intestinal health (Harcourt-Brown and Harcourt-Brown, 2012). The elevation in plasma glucose concentration in the control group might be attributed to a reduction in glucose utilization in order to maintain energy in heat stress conditions (Hassan *et al.*, 2016). Marai *et al.* (1999) attributed the reduction in blood plasma glucose (by 20.7% in NZW rabbits) to the remarkable mitigation of blood and body blobs or to the rise in glucose employment to make more power for higher muscular disbursement needed for the elevated respiratory action during heat stress. Nocturnal feeding showed low stress on the rabbits, whereas the cortisol concentrations were low. When animals kept under heat stress conditions, albumin was low (Marai *et al.*, 1999). The reduction in AST and ALT activities in the existing work might be assigned to a decreased energizing of gluconeogenesis by the reduction in cortisol. Abdel-Monem *et al.* (2007) obtained comparable outcomes. ALT

activity was lower while, total proteins levels were greater in rabbits fed nocturnally than those of diurnal feeding (Daader *et al.*, 2002).

Behavioral patterns, rectal temperature and health risks.

The lowest ($P < 0.05$) value of rectal temperature was observed in rabbits of T3 (Table 5). Insignificant effects of feeding program (times and quantities) were found on behavioral patterns and health risks (%). Also, mortality and morbidity percentages were not influenced by feeding program (data not shown). Changing feeding program significantly reduced rectal temperature especially in rabbits of T3 group, and it was a strategy to improve health status of rabbits. The elevation in rectum temperature under heat stress might be attributed to the fall of the physiological ways (Marai *et al.*, 2001).

Table 5. Effect of feeding program on behavioral patterns, rectal temperature and health risks of male growing rabbits.

Traits	Treatment groups				SEM	P value	
	C	T ₁	T ₂	T ₃			T ₄
<i>Behavioral patterns</i>							
Resting	1.82	1.76	2.22	2.68	2.80	0.46	0.5719
Locomotor	2.60	2.40	1.80	1.66	1.94	0.33	0.4366
Grooming	0.80	0.67	0.65	0.46	0.28	0.08	0.3142
Investigatory	0.07	0.06	0.06	0.02	0.04	0.01	0.4352
Agonistic	0.00	0.07	0.08	0.00	0.00	0.02	0.1254
<i>Rectal temperature</i>	40.45 ^a	40.19 ^{ab}	39.67 ^b	39.55 ^b	39.63 ^b	0.08	0.0504
<i>Health risk, %</i>	10.22	11.16	9.45	5.88	8.36	1.76	0.3377

^a and ^b Means within each row for each division with no common superscripts are significantly different ($p \leq 0.05$).

The rise in respiration activity is concerning to the rise in ambient temperature and thus helps the rabbits to waste heat. Rabbits fed nocturnally had lower rectal temperature than those fed diurnally (Daader *et al.*, 2002). At night, heat output decreases by 5% as compared with the day, and that reduction in heat output may outcome from low activity and resting or sleeping (Szendro *et al.*, 2004). Melatonin decreases heat output during darkness, by dropping body temperature and adjusting heat waste (Rozenboim *et al.*, 1998). Rabbits utilize body position as a tool to modify heat loss (Marai *et al.*, 2004). In this investigation, rabbits of T₃ group had the highest value of resting behavior and the lowest ones of locomotion, investigation and agonistic, indicating the feeding program of 25% at morning and 75% at night was more suitable for growing rabbits. The circadian difference in behaviors suggests the variations in these behavioral attributes following day time (Gidenne *et al.*, 2012; Ogbu *et al.*, 2014). The high health risks in the control and T₁ groups

could be due to the heat stress and to the stress of feed existence during the day. It could be suggested that, based on our findings, feeding limited feed quantities across the day and giving the main quantity during the night induced an improvement in rabbits health. Similar findings were found by Tůmová *et al.* (2003) and Duperray *et al.* (2012). Ojebiyi *et al.* (2015) reported insignificant differences in rectal temperature among rabbits fed *ad libitum*, nocturnal and diurnal.

Conclusion

There were favorable effects due to changing feeding times and quantities over the day on growth performance traits. Changing feeding times and quantities significantly reduced rectal temperature and it was a strategy to improve the health status of the rabbits. Feeding at the night is highly recommended for growing rabbits under heat stress of summer months.

Ethical Approval: All experimental procedures followed the guidelines of the Ethical committee of Assiut University.

Competing Interests: There is no conflict of interest.

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نظم التغذية يمكنها تحسين أداء النمو والحالة الفسيولوجية في أرانب النيوزيلندي النامية في فصل الصيف في مصر

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تم دراسة تأثيرات نظام التغذية (وقت وكمية) على بعض صفات النمو، المكونات الحيوية للدم ، صفات الذبيحة ، السلوك لذكور الأرانب النيوزيلندي خلال فصل الصيف. استخدم في هذه الدراسة عدد ٨٠ ذكر نيوزيلندي مفلوم ($735 \pm 4.7 \text{ gm}$) حيث تم تقسيمهم عشوائيا الى ٥ مجاميع تجريبية. أرانب المجموعة الأولى (الكونترول) تم تغذيتهم حتى الشبع. أرانب المجموعة الثانية (C1) تم تغذيتهم على ٧٥% من العليقة صباحا و ٢٥% من العليقة ليلا. أرانب المجموعة الثالثة (T2) تم تغذيتهم على ٥٠% من العليقة صباحا و ٥٠% من العليقة ليلا. أرانب المجموعة الرابعة (T3) تم تغذيتهم على ٢٥% من العليقة صباحا و ٧٥% من العليقة ليلا. أرانب المجموعة الخامسة (T4) تم تغذيتهم على ١٠٠% من العليقة ليلا. **أظهرت النتائج** ان أرانب المجموعة الرابعة (T3) أظهرت أثقل وزن جسم و أعلى زيادة وزن مكتسب وأفضل معدل تحويل غذائي خلال العمر من ١٤ - ١٦ أسبوع. أرانب المجموعتان الرابعة (T3) والخامسة (T4) أظهرت أعلى نسبة تصافى للذبيحة وأقل نسبة دهن بطن. أرانب المجموعة الرابعة (T3) أظهرت أقل نشاط للألنين امينوترانسفيريز (AST) وأقل قيمة لحرارة المستقيم وأعلى تركيز للجلوكوز. **التوصية:** يفضل التغذية ليلا في مزارع الأرانب نتيجة لتأثيرها المفيد على النمو تحت ظروف الجو الحار صيفا في مصر.