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GROWTH PERFORMANCE, NUTRIENTS UTILIZATION AND CARCASS TRAITS OF GROWING CALIFORNIAN RABBITS RAISED UNDER DIFFERENT AMBIENT TEMPERATURES

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A total of 60 male Californian rabbits of 6 weeks of age in Saudi Arabia were used to investigate the effects of three ambient temperatures of 20° C (Control), 26 ° C (Moderate) and >32 ° C (High) on growth performance, feed intake, feed conversion, digestibility and nitrogen-balance. Coefficients of digestion, feeding value, nitrogen retention and biological value were evaluated. Slaughter test was also performed at 12 and 16 weeks of age to investigate the effects of such temperatures on carcass traits, carcass composition and chemical composition of the rabbit lean meat.

*Californian rabbits raised under high temperature (>32 ° C) up to 12 weeks of age lost 8.5% of their body weights and feed intake was reduced by 30%. At 16 weeks of age, rabbits in all treated groups showed similar live weight. Exposure to >32 ° C insignificantly affected feed conversion of all ages studied. The digestibility trial showed that the high temperature was associated with 43% reduction in all nutrients taken, while nutrient outputs were halved for rabbits raised at >32° C compared to those raised at 20 ° C. Coefficients of digestion for **DM**, **CP**, **CF** and **NFE** increased as the ambient temperature increased, while digestibility of **EE** was not affected by heat treatments. Most of the carcass traits at the two ages studied were insignificantly affected by high temperature (>32 ° C). Rates of change in carcass traits attained in rabbits exposed to high temperature compared to rabbits of the control group were low or moderate and ranged between -14.9 and 8.8% for carcass of 12 weeks of age, and between -18.2 and 7.7% when rabbits were slaughtered at 12 and 16 weeks of age, respectively, i.e. rate of change at 12 weeks of age was higher than at 16 weeks of age. More lean with less fat content (P<0.05) was attained in carcasses of rabbits exposed to the high temperature when compared to carcasses of rabbits reared under the control group (20° C), while bone contents of the carcass were similar in all treated groups. Dry matter and ash in the* *lean composition of carcass were ,nearly similar in all treated groups, while insignificant more CP and less EE were recorded for the lean of the high temperature group. Under high temperature, it is preferable to slaughter rabbits at 12 weeks of age.*

Key words: Rabbits, ambient temperature, growth, nutrients utilization, carcass.

Under hot conditions, rabbit requires a high dissipation of heat to maintain a constant body temperature, while in cold environment the metabolism must be increased to produce sufficient heat for the same reason. The literature showed that the efficiency of nutrients utilization of a diet by the rabbit decreases as the environmental temperature increases, although feed digestibility increases (Fuquary, 1981). This is due to the decrease of feed intake and the occurrence of some alterations in the digestive physiology (Gidenne, 1996).

In Saudi Arabia, hot arid climate is considered one of the main limiting and constraining factors to raise, economically, standard breeds of rabbits (e.g. New Zealand White and California). Raising these breeds of rabbits particularly in small-scale yards, needs some special methods to reduce the adverse effects of heat stress on their performance (Maria et al, 1994).

The present work aimed to study the growth performance of Californian rabbits raised under three ambient temperatures of about 20±1, 26±1 and 32 ± 2°C. Nutrients digestibility, nitrogen balance, carcass traits and lean meat composition (%), were evaluated under the same environmental temperatures. A further objective was to detect which age is preferable to slaughter rabbits at 12 or 16 weeks of age under such conditions.

MATERIALS AND METHODS

The present experiment was carried out at the Rabbit Research Unit of the Department of Animal Production and Breeding, College of Agriculture and Veterinary Medicine in Al-Qassim, King Saud University, Kingdom of Saudi Arabia. The experiment started in October 1997 and lasted for 10 weeks.

Temperature-treated groups and management:

Sixty males Californian rabbits of the same age (6-week old) were obtained from a private farm in El-Qassim region (about 320 km to the north of Riyadh), Saudi Arabia. Rabbits were divided into three experimental groups, 20 rabbits each, and they were kept in three separate rooms adjusted for three ambient temperatures, i.e. about 20 ± 1, 26 ± 1 and $>32 \pm 2$°C for treatments **C** (control), **M** (moderate) and **H** (high). Rabbits of the experimental treatments were kept in closed rabbitry and were subjected to the same managerial and hygienic conditions. In Al-Qassim region, climate is always arid and the relative humidity does not exceed 5%.

Animals were housed in individual galvanized metal wire cages (40 x 40 x 40 cm) arranged in double-tier batteries (California type). The batteries were accommodated with feeders and automatic drinkers. Temperature was controlled using separate electric heaters and air-conditioners, while the ventilation was controlled using electric extractor fans. During the whole period of the experiment, no rabbits were died in all heat-treated groups.

Feeding

Rabbits were fed on a commercial growing pelleted diet during the whole experimental period (10 weeks). On dry matter (**DM**) basis, the diet contained 17.19% crude protein (**CP**), 15.57% crude fiber (**CF**), 2.45% ether extract (**EE**), 58.5% nitrogen-free extract (**NFE**) and 6.29% ash. Feed and water were available *ad libitum*. The metabolizable energy (**ME**) of the given diet was calculated according to the equation described by Kalogen (1985) as follows:

$$\mathbf{ME}\ (\text{kcal/kg}\ \mathbf{DM}) = (0.588 + 0.164\mathbf{X})\ 239$$

where **X** is the digestion coefficient of the dry matter.

Growth and feeding parameters

Rabbits were individually bi-weekly weighed from 8 to 16 weeks of age. The traits under study included live body weight, daily weight gain, daily feed intake and feed conversion (g feed/g gain).

Digestibility and nitrogen-balance trial

The digestibility trial of the present study took place at 8 weeks since Perez *et al*. (1996) reported that the best digestive efficiency obtained when the growing rabbits are at the age of about 7 weeks. Twelve rabbits were used in the digestibility and N-balance trial according to the European reference method (Perez *et al*., 1995). Four animals from each environmental treatment were housed individually in metabolism cages and were given *ad libitum* the experimental diet from 6 weeks of age. After an adaptation period of 2 weeks, the total faecal excretions were collected daily in plastic bags and stored at - 10°C for 7 days. To measure nitrogen balance, urine during the same collection period was also collected daily in plastic bottles containing 10 ml 1N H_2SO_4 to avoid ammonia loss and they were freezed to be chemically analyzed. The complete chemical composition of feed, remainder feed and faeces were determined according to A.O.A.C. (1990). Nitrogen in urine samples was determined by the Micro-Kjeldahl method. Feed intakes were determined daily by subtracting the residual feeds from the daily allowances.

In the digestibility trial, data on nutrients intake and output, coefficients of digestion and feeding value [in terms of total digestible nutrients (**TDN**), digestible crude protein (**DCP**) and nutritive ratio (**NR**)] were calculated. Data of nitrogen intake, faecal and urinary nitrogen, nitrogen retention and biological value were also recorded as parameters of the nitrogen balance.

Slaughter test

At 12 and 16 weeks of age, a total number of 33 rabbits (representing averages of the experimental groups) were randomly taken for slaughter test (11 rabbits from each treatment; 6 rabbits at 12 weeks and 5 rabbits at 16 weeks of age). Rabbits were weighed just before slaughtering as well as after complete bleeding. Rabbits carcasses were dissected according to Blasco *et al* (1993) and cutable edible and non-edible parts were recorded. The head (**HEW**), fur (**FW**), heart (**HW**), liver (**LW**), kidneys (**KW**), lungs (**LUW**), viscera (**VW**), chest (**CW**), loin (**LOW**), front-parts (**WFP**) and hind-parts (**WHP**) were weighed. Hot carcasses (**HCW**) were weighed and dressing percentages (**D%**) were calculated. For lean composition traits, all carcasses were divided longitudinally into two similar halves. The right half was separated into four parts (i.e. front-part, hind-part, chest and loin) which were separated into lean fat and bone. Lean of each half was separated and prepared for chemical analysis. Dry matter (using an air evacuated oven for 16 h), crude protein (N × 6.25), ether extract and ash in the lean were determined according to A.O.A.C. (1990).

Statistical analysis

Data of the present investigation were analyzed using **GLM** procedure of the **SAS** program, version 6.12 under Windows 95 (**SAS**, 1996). Data of growth performance, daily feed intake and feed conversion were analyzed using the following linear model:

$$\mathbf{Y_{ijk} = \mu + A_i + B_j + AB_{ij} + e_{ijk}} \qquad \textbf{(Model 1)}$$

where Y_{ijk} =The observation on the ijkth rabbit; μ = Overall mean; $\mathbf{A_i}$ =The effect of the ith ambient temperature (i = 1, 2, 3); $\mathbf{B_j}$= The effect of jth class of initial weight; $\mathbf{AB_{ij}}$=The interaction effect between $\mathbf{A_i}$ and $\mathbf{B_j}$ and $\mathbf{e_{ijk}}$ = a random error assumed to be independently randomly distributed with zero mean and variance σ^2_e , i.e. NID (0, σ^2_e).

Data of carcass traits were analyzed for each age separately (8 and 12 weeks) using the following linear model:

$$\mathbf{Y_{ijk} = \mu + A_i + D_j + AD_{ij} + e_{ijk}} \qquad \textbf{(Model 2)}$$

where $\mathbf{D_j}$ =The effect of the $\mathbf{j^{th}}$ class of preslaughter weight (categorized with interval of 200 grams); $\mathbf{AD_{ij}}$= The interaction effect between $\mathbf{A_i}$ and $\mathbf{D_j}$; other symbols as defined in Model 1.

The traits of digestibility and nitrogen balance were analyzed using the following linear model:

$$\mathbf{Y_{ij} = \mu + A_i + e_{ij}} \qquad \textbf{(Model 3)}$$

All symbols of Model 3 are as defined in **Model 1.**

Percentages of chemical composition of meat were analyzed by adopting the following linear model:

$$\mathbf{Y_{ikl} = \mu + A_i + C_k + AC_{ik} + e_{ikl}} \qquad \textbf{(Model 4)}$$

where C_k =The effect of the kth age; AC_{ik} =The interaction effect between A_i and C_k; other symbols as defined in **Model 1.**

Since carcass traits at 12 and 16 weeks of age were taken from four cutable regions (front-part, hind-part, loin and chest), therefore, data of carcass composition (i.e. percentages of bone, lean and fat) were analysed using a linear model including three main factors as:

$$Y_{iklm} = \mu + A_i + C_k + R_l + AC_{ik} + AR_{il} + CR_{kl} + e_{iklm} \text{ (Model 5)}$$

where R_l = The effect of the l^{th} cutable region; AR_{il} =The interaction effect of A_i and R_l; CR_{kl} = The interaction effect of C_k and R_l; other symbols as defined in **Models 1 & 4.**

All data measured as percentages were subjected to arc-sin transformation to approximate normal distribution before being analyzed.

RESULTS AND DISCUSSION

Growth and feeding performance :

Growth performance of Californian rabbits raised in the three ambient temperatures [control (**C**), moderate (**M**) and high (**H**)] are presented in Table 1. In general, high temperature lead to a reduction in live body weight ($P<0.05$ or $P<0.01$). During the first two weeks (8-10), body weight was not affected under the ambient temperature of 26±2°C while it decreased by 8.5% under temperatures of more than 32°C during the same period. During the subsequent two weeks of growth (10-12), groups **G** and **H** showed a loss in body weight of 7.6 and 13.4%, respectively ($P<0.01$). During the last period of the study (12-16 weeks), rabbits kept under the comfort temperature (Group **C**) weighed more than the other two heat-treated groups which were almost similar.

Daily gain in weight (Table 1) followed the same trend recorded for body weight, since rabbits raised under high temperature (>32°C) gained less than those rabbits kept under the temperature of 20°C. During the period of 12-16 weeks, all rabbits in all treatments gained almost equally. This may indicate that the older rabbits could be more resistant for high ambient temperature.

Daily feed intake was significantly ($P<0.01$) reduced as the ambient temperature increased (Table 1). The reduction was about 30% under high temperature during the whole experimental period. On the other hand, the ambient temperatures under which the experimental animals were kept (Table 1) did not significantly affect feed conversion ratio (g feed/g gain). This was obviously due to the reduction in body gain weight along with the reduction in feed intake. Particularly during the first weeks of the experiment, rabbits were more efficient in converting their feeds into gain

Table 1. Least squares means (± SE) of growth performance of growing Californian rabbits kept under three ambient temperatures.

Trait	Ambient Temperature (T)						Initial weight (IW)	T × W Interaction	RSD[+]
	No	Group C (20°C)	No	Group M (26 °C)	No	Group H (>32 °C)			
Live body weight (g)									
at 10 week	20	2070 ± 25^a	20	2043 ± 25^a	18	1894 ± 26^b	***	ns	90.2
at 12 week	20	2597 ± 46^a	20	2399 ± 46^b	17	2248 ± 50^c	***	ns	167.4
at 16 week	11	3451 ± 87^a	14	3178 ± 85^b	12	3137 ± 86^c	**	ns	248.4
Daily weight gain (g)									
8 - 10 weeks	20	27.4 ± 2.1^a	20	30.0 ± 2.1^a	18	20.1 ± 2.1^b	ns	ns	7.5
10-12 weeks	20	35.2 ± 2.8^a	20	23.7 ± 2.8^b	17	23.6 ± 3.0^b	**	ns	10.2
12-16 weeks	11	32.0 ± 1.0^a	14	29.9 ± 0.8^a	12	29.3 ± 0.9^a	ns	ns	7.3
Daily feed intake (g)									
6 - 8 weeks	20	120.1 ± 2.8^a	20	112.4 ± 2.8^b	18	87.8 ± 2.9^c	ns	ns	10.1
8-10 weeks	20	161.7 ± 3.5^a	20	127.9 ± 3.5^b	17	115.2 ± 3.7^c	ns	ns	12.5
10-12 weeks	20	158.8 ± 3.5^a	20	144.7 ± 3.5^b	17	120.9 ± 3.7^c	ns	ns	12.5
Feed conversion (g feed/g gain)									
8 - 10 weeks	20	5.1 ± 0.4^a	20	4.0 ± 0.4^a	18	5.1 ± 0.4^a	ns	**	1.37
10-12 weeks	20	5.3 ± 0.4^a	20	5.8 ± 0.4^a	17	5.3 ± 0.5^a	*	ns	1.57
12-16 weeks	11	10.3 ± 1.3^a	14	12.4 ± 1.0^a	12	10.0 ± 1.2^a	ns	ns	3.72

[+] RSD = Residual standard deviation.

[a,b,c] Values having different superscripts within each row differ significantly (P<0.05 or P<0.01)

ns= non-significant; *= P<0.05; **= P<0.01; ***= P<0.001

(4.0-5.8 g feed/g gain), while efficiency of feed conversion reduced sharply (10.0-12.4 g feed/g gain) at older ages (12-16 weeks). This was mainly due to that maintenance requirements for rabbits were high along with lower rate of growth from 12-16 weeks compared to the rate of growth attained from 8 to 12 weeks of age. Generally, Stephan (1980) and Yamani and Farghally (1994) indicated that exposure of growing rabbits to high temperature was associated with reduction in live body weights and gains, feed intake, and feed conversion, and an increase in disease incidence, which all in turn reduced the economic returns. The poor growth performance of rabbits under high temperature results mainly from the decrease in feed intake which leads to less protein biosynthesis and/or less fat deposition. Moreover, the increase in respiration rate, body temperature and heart impulse rate may consume more energy and accordingly the remaining net energy for growth is decreased (Marai *et al,* 1994).

Digestibility of nutrients

Apparent digestibility of all nutrients increased as ambient temperature elevated (Table 2). This effect was more pronounced in the digestibility of **CP** and **CF**. Higher coefficients of digestibility were mainly due to the decrease in nutrients output as shown in Table 2. This may be due to the lower flow rate of the digesta in the gut that allow to the nutrients to act with the digestive enzymes for longer time. Gidenne (1996) reported that in order to have a comprehensive view of cecal transit, studies of function should be coupled with studies of digesta passage time. However, measurement of cecal digesta rate of passage would require implantation of a cannula or catheter in the ileum and the proximal colon, which is very difficult.

Digestibility of **DM**, **CP**, **CF** and **NFE** significantly (P<0.01) increased as the environmental temperature increased, while the apparent digestibility of **EE** was not affected (Table 2). Skrivanova *et al.* (1998) reported no differences in digestibility of nutrients between two heat-treated groups of rabbits kept under 6 or 25°C. In the present results, the rates of change in digestion of nutrients for group **H** compared to group **C** were low or moderate and ranged from 3.7% for **NFE** to 20.4% for **CP**. The higher digestibility of **CF** by rabbits exposed to high ambient temperature may be interpreted from the fact that rabbits in the heat stress-group with less feed intake may keep **CF** in the cecum for longer time leading to more digestion by microflora. Many investigators (Hoover and Heitmann, 1972; Champe

able 2. Least squares means (± SE) of nutrients intake and output, and coefficients of digestibility for rabbits kept under three environmental temperatures.

tem	No.	DM	CP	EE	CF	NFE
Nutrient intake (g/d):						
Control (20°C)	4	136.00[a]	23.40[a]	3.43[a]	21.20[a]	79.58[a]
Moderate (26°C)	4	110.75[b]	19.05[b]	2.80[b]	17.28[b]	64.80[b]
Hot (> 32°)	4	95.25[c]	16.38[c]	2.40[c]	14.88[c]	55.70[c]
± SE		4.46	0.77	0.11	0.70	2.61
RSD[+]		8.91	1.53	0.23	1.39	5.21
Nutrient output (g/d):						
Control (20°C)	4	41.33[a]	7.88[a]	0.93[a]	16.58[a]	11.45[a]
Moderate (26°C)	4	30.43[b]	5.13[b]	0.90[a]	11.90[b]	6.73[b]
Hot (> 32°)	4	21.50[c]	3.18[c]	0.50[b]	8.50[c]	6.23[b]
± SE		1.78	0.26	0.10	0.55	0.73
RSD[+]		3.55	0.51	0.21	1.10	1.45
Coefficients of digestibility (%):						
Control (20°C)	4	69.62[a]	66.35[a]	72.90[a]	21.80[a]	85.63[a]
Moderate (26°C)	4	72.52[b]	73.03[b]	68.08[a]	31.00[b]	89.63[b]
Hot (> 32°)	4	77.43[c]	80.45[c]	78.98[a]	42.83[c]	88.78[b]
± SE		1.11	1.17	3.34	2.63	0.90
RSD[+]		2.23	2.33	6.68	5.25	1.79

SD= Residual standard deviation

DM = Dry matter; **CP** = Crude protein; **EE** = Ether extract; **CF** = Crude fibre; **NFE** = Nitrogen-free extract.

[a,b,c,] Values having different superscripts within each item under each column differ significantly (P<0.01).

SE = Standard error.

and Maurice, 1983; Abou-Ashour and Ahmed, 1986; Strucklec *et al*., 1994; Garcia *et al*., 1995; Bellier and Gidenne, 1996) reported no significant changes in the concentration of the fermentation end-product (ammonia and VFA) which mean that the cecal microbial activity (digestion) remains high with less fibre available.

The intakes of total digestible nutrients (**TDN**) was 80 and 73 g/d in groups **M** and **H**, respectively compared to 93 g/d in group **C**. The metabolizable energy (**ME**) values of the diet were improved to be 2869, 2983 and 3175 kcal/kg of **DM** in Groups **C**, **M** and **H**, respectively. **ME** intakes were 390, 330 and 302 kcal/d in the three respective groups, while the protein intakes were 15.55, 13.93 and 13.19 g/d, respectively.

Least squares means of the feeding values [expressed as total digestible nutrients (**TDN**) and digestible crude protein (**DCP**)] for Californian rabbits raised under the three ambient temperatures are presented in Table 3. These values were increased (P< 0.01) as the temperature increased. **TDN** improved by 6.7% and 11.45% with rabbits raised under groups **M** and **H**, respectively. The respective values of improvement for **DCP** were 9.14% and 21.17% and for nutritive ratio (**NR**) were 4.04% and 11.1%. This was mainly due to the improvement in digestibility of nutrients as discussed above.

Nitrogen balance

Data of nitrogen balance are shown in Table 4. Trend of nitrogen intake and output was similar to the trend of the other nutrients, i.e. nitrogen intake, faecal nitrogen and urinary nitrogen decreased with the increase of room temperature in which rabbits were raised. Animals under heat stress also released less nitrogen in their urine. By this mechanism, rabbits in Group **H** retained the required nitrogen for their tissues growth by 42.7% compared to rabbits of Group **C**. Nitrogen retention was almost equal in all the experimental groups. Biological value of the dietary protein improved under high temperature by 6.1% for rabbits of Group **M**, and by 22.7% for Group **H** compared to Group **C**. This was mainly due to the decrease in nitrogen intakes, while nitrogen retention was similar in all treated groups.

Carcass traits

For carcass traits at both ages of slaughtering (Table 5), most of these traits (**HCW**, **D%**, **WFP**, **WHP**, **LOW**, **LW**, **KW**, **HW** and **VW**)

Table 3. Least squares means (± SE) of the feeding values for Californian rabbits raised under three ambient temperatures

Heat-treated groups	No	TDN %	DCP %	NR
Control (20°C)	4	69.00^a	11.43^a	5.05^a
Moderate (26°C)	4	73.65^b	12.58^b	4.85^a
Hot (> 32°)	4	76.90^c	13.85^c	4.55^b
± SE		0.99	0.19	0.07
RSD$^+$		1.98	0.39	0.14

$^+$**RSD** = Residual standard deviation

TDN = Total digestible nutrients; **DCP** = Digestible crude protein; **NR**= Nutritive ratio = **(TDN-DCP) / DCP.**

^{a,b,c,} Values having different superscripts within each column differ significantly (P<0.01). **SE** = Standard error.

Table 4. Least squares means (± SE) of nitrogen intake (NI), faecal nitrogen (FN), urinary nitrogen (UN), nitrogen retention (NR) and biological value (BV) for rabbits kept under the three ambient temperatures.

Heat-treated groups	No.	NI (g/d)	FN (g/d)	UN (g/d)	NR (g/d)	BV (%)
Control (20°C)	4	3.74^a	1.26^a	1.29^a	1.19^a	47.95^b
Moderate (26°C)	4	3.05^b	0.82^b	1.10^a	1.14^a	50.88^{ab}
Hot (> 32°)	4	2.62^c	0.50^c	0.87^b	1.25^a	58.85^a
± SE		0.12	0.04	0.06	0.11	2.73
RSD$^+$		0.24	0.08	0.12	0.21	5.47

$^+$**RSD** = Residual standard deviation

^{a,b,c} Values having different superscripts within each column differ significantly (P<0.05 or P<0.01).

BV = NR/(NI-FN).

SE = Stander error.

Table 5. Least squares means (± SE) of carcass characteristics for Californian rabbits raised under three ambient temperatures and slaughtered at 12 or 16 weeks of age.

Item	HCW (g)	D%	WFP (g)	WHP (g)	LOW (g)	CW (g)	LW (g)	KW (g)	HW (g)	LUW (g)	VW (g)	HEW (g)	FW (g)
At 12 weeks													
Temperature group (T):													
Control (20°C)	1390^{a}	55.8^{a}	261^{a}	495^{a}	360^{a}	247^{a}	98.4^{a}	22.1^{a}	7.2^{a}	16.8^{a}	215^{a}	223^{a}	272^{a}
	± 55	± 1.5	± 12	± 23	± 21	± 11	± 7.1	± 1.4	± 0.8	±0.8	± 12	± 5.4	± 8.3
Moderate (26°C)	1381^{a}	57.0^{a}	278^{a}	473^{a}	391^{a}	217^{ab}	80.2a	22.7^{a}	8.7^{a}	16.7^{ab}	195^{a}	225^{a}	252^{b}
	± 55	± 1.5	± 12	± 23	± 21	± 11	± 7.1	± 1.4	± 0.8	± 0.8	± 12	± 5.4	± 8.3
High (> 32°C)	1426^{a}	59.0^{a}	265^{a}	493^{a}	392^{a}	253^{b}	93.4^{a}	23.0^{a}	6.6^{a}	14.9^{b}	183^{a}	215^{b}	258^{b}
	± 61	±1.6	± 13	± 26	± 23	± 12	± 7.9	± 1.5	± 0.8	± 0.9	± 13	± 5.9	± 9.2
Initial weight (IW)	**	ns	***	*	**	*	ns	*	ns	*	ns	***	***
T × IW	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	ns
RSD^{+}	121.5	3.24	25.5	51.6	46.4	23.6	15.7	3.11	1.68	1.74	25.6	11.9	18.4
At 16 weeks													
Temperature group (T)													
Control (20°C)	1795^{a}	56.2^{a}	323^{a}	568^{a}	527^{a}	308^{ab}	98.5^{a}	26.7^{a}	7.7^{a}	19.5^{a}	221^{a}	275^{a}	396^{a}
	± 60	± 0.9	± 13	± 27	± 40	± 22	± 9.4	± 4.9	± 0.5	± 2.6	± 16.1	± 9.1	± 18
Moderate (26°C)	1903^{a}	54.5^{a}	339^{a}	601^{a}	419^{a}	482^{a}	103.9^{a}	27.4^{a}	9.8^{a}	19.7^{a}	244^{a}	298^{a}	419^{ab}
	± 60	± 0.9	± 13	± 27	± 40	± 22	± 9.4	± 4.9	± 0.5	± 2.6	± 16.1	± 9.1	± 18
High (> 32°C)	1798^{a}	56.9^{a}	302^{a}	612^{a}	525^{a}	298^{b}	80.6^{a}	22.3^{a}	7.7^{a}	16.6^{a}	201^{a}	272^{a}	348^{b}
	± 49	± 0.8	± 11	± 22	± 33	± 18	± 7.7	± 4.9	± 0.4	± 2.1	± 13.2	± 7.4	± 15
Initial weight (IW)	***	ns	***	**	ns	***	*	ns	***	ns	**	***	***
T × IW	Ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	ns
RSD^{+}	106.7	1.77	23.3	49.2	71.9	39.2	16.9	8.75	0.96	4.64	28.9	16.2	33.0

$^{+}$RSD = Residual standard deviation

HCW= Hot carcass weight; **D**= Dressing %; **WFP**= Weight of front part; **WHP**= Weight of hind part; **LOW**= Loin weight; **CW**= Chest weight; **LW**= Liver weight; **KW**= Kidney weight; **HW**= Heart weight; **LUW**= Lung weight; **VW**= Viscera weight; **HEW**= Head weight; **FW**= Fur weight.

^{a,b} Values having different superscripts within each column differ significantly (P<0.05 or P<0.01)

ns = Non-significant; *= P<0.05; **= P<0.01; ***= P<0.001

were not significantly affected by high temperature (>32°C). On the other hand, some of the edible (**CW** and **HEW**) and the non-edible (**LUW** and **FW**) parts of the carcass were considerably affected ($P<0.05$) by the same factor (Table 5). Some of the differences in weights of carcass parts could be due to differences in the carcass fat content, as reported by Lukefahr *et al* (1983) and Ozimba and Lukefahr (1990). This is clear for carcass traits measured at 16 weeks of age. Chiericato *et al.* (1992&1993) reported higher values of fat deposits in the rabbits reared under low temperature (12°C) compared to the rabbits reared under high temperature (30°C).

In general, high temperature treatment lead to a slight increase in **HCW**, **D%**, **WHP** and **LOW**, while little reductions in **WFP**, **CW**, **KW** (at 16 weeks of age), **HW**, **LUW**, **VW**, **HEW** and **FW** (at both ages) were observed. Therefore, high ambient temperature of 32°C may have a little contribution in the variation of carcass traits of the Californian rabbits at the two ages studied (12 and 16 weeks). This notation is evidenced from results of the increasing or decreasing rates in different carcass traits resulted from the increase of the temperature in Group **H** compared to the Group **C**. In this respect, the rates of change in carcass traits at 12 weeks of age attained from Group **H** compared to Group **C** were 2.6% for **HCW**, -5.4% for **D%**, 1.5% for **WFP**, -0.4% for **WHP**, 8.8% for **LOW**, 2.4% for **CW**, -5.1% for **LW**, 4.1% for **KW**, -8.3% for **HW**, -11.3% for **LUW**, -14.9% for **VW**, -3.6% for **HEW**, and -5.1% for **FW**, while the respective rates of changes at 16 weeks of age were 0.2, 1.2, -6.5, 7.7, -0.4, -3.2, -18.2, -16.4, 0.0, -14.9, -9.0, -1.1 and -12.1% . These rates of change indicate also that offal (**LW** and **KW**) and some non-edible parts of the carcass (**VW**, **LUW** and **FW**) are somewhat changed under the high-temperature treatment, while traits of the most edible parts are not changed.

Carcass composition

Percentages of bone, lean and fat in carcasses of the three groups are shown in Table 6. For Group **H** (>32°C), carcasses had significantly more lean and less fat percentages ($P<0.05$) than to the control group, while bone percentages were similar in all heat-treated groups. Therefore, rabbits raised in hot areas like Saudi Arabia may be rich in their meat and this meat could be characterized by high lean with low fat content. Consequently, high content of protein and low content of cholesterol may characterize meat of rabbits raised under high temperature. These results were in complete agreement with the data recorded by the trial of the digestibility and N-

Table 6. Least squares means (± SE) of percentages of bone, lean and fat in the whole carcass and in different cuts of the rabbits kept under the three ambient temperatures and slaughtered at 12 or 16 weeks of age.

Item	No.[@]	Bone %	Lean %	Fat %
Ambient Temperature (T):				
Control (20°C)	55	8.22[a]	82.91[b]	8.88[a]
Moderate (26°C)	55	8.36[a]	82.56[b]	9.08[a]
Hot (> 32°)	55	8.48[a]	84.71[a]	6.81[b]
± SE		0.19	0.50	0.50
Age (A):				
12 weeks	75	8.35[a]	84.38[a]	7.29[b]
± SE		0.15	0.39	0.39
16 weeks	90	8.36[a]	82.42[b]	9.23[a]
± SE		0.16	0.43	0.43
Cuts region (CR):				
Front part	33	7.22[c]	78.72[c]	14.06[a]
Hind part	33	8.04[b]	89.39[a]	2.57[e]
Loin	33	7.61[bc]	80.35[c]	12.07[b]
Chest	33	10.69[a]	84.77[b]	4.71[d]
Whole carcass	33	8.20[b]	83.93[b]	7.87[c]
± SE		0.24	0.64	0.65
T × A		ns	***	***
T × CR		ns	ns	ns
A × CR		ns	ns	ns
RSD[+]		1.39	3.68	3.70

[+] **RSD** = Residual standard deviation

[a,b,c,d,e] Values having different superscripts within each column under each item differ significantly (P<0.05 or P<0.01).

ns= Non-significant (P>0.05), *** = P < 0.001

[@] Total number of observations = 33 animals × 5 regions = 165

SE = Standard error.

balance (Table 2). Pla (1998) found that carcasses of the rabbits raised under heat-stress (at 30°C) were more compact and less fattened.

Rabbits slaughtered at 12 weeks had more lean and less fat than those slaughtered at 16 weeks ($P<0.05$), while the bone percentages in both ages were equal (Table 6).

Percentages of bone, lean and fat in different cutable regions were also determined and they are presented in Table 6. Obviously, the chest region had the highest bone percentage ($P<0.05$), followed by the hind part and the loin, while the front part was the lowest. Regarding the lean percentage, the hind part was the highest followed by the chest then the loin region, while the front part was the lowest. For fat percentage in meat, the hind part ranked first (very low with 2.6%), followed by the chest (4.6%) and loin (11.9%), while the front part ranked the latest (14%). Lukefahr *et al.* (1989) stated that the cutable regions of the hind part and the chest of the carcass of the rabbit are generally characterized by very low content of cholesterol in meat.

Lean and fat contents of carcass were significantly ($P<0.001$) affected by temperature × age interaction (Table 6). Consequently, lean and fat contents for carcass of rabbits slaughtered at a certain age (12 or 16 weeks) and raised under high environmental temperature (>32°C) may be of considerable advantage compared to rabbits raised under temperature of 20°C or 26°C. Other interactions of temperature × cutable region and age × cutable region were of little importance and they had insignificant effects on all percentages of the composition of the carcass.

Meat chemical composition

Meat chemical composition presented in Table 7 showed that **DM** and ash contents recorded by groups **M** and **H** were similar to those recorded by group **C**, i.e. **DM** and ash contents were quit similar in all treated groups. But under high temperature (>32°C), rabbits meat had more **CP** and less **EE** although the differences were not significant.

Comparison between meat of rabbits slaughtered at 12 weeks and 16 weeks showed that meat of rabbits at 16 weeks had more **DM** and **EE** and less contents of ash and **CP** than those at 12 weeks (Table 7). The differences were significant only for **DM** and ash contents. Bieniek *et al*

Table 7. Least squares means (± SE) of meat chemical composition for rabbits kept under the three ambient temperatures and slaughtered at 12 or 16 weeks of age.

Item		No.	DM	CP	EE	Ash
			%	%	%	%
Ambient temperatures (T):						
Control (20°C)		11	36.43[a]	62.77[a]	32.90[a]	4.32[a]
Moderate (26°C)		11	37.45[a]	67.23[a]	27.91[a]	4.85[a]
Hot (> 32°)		11	36.13[a]	68.38[a]	26.95[a]	4.68[a]
	± SE		0.89	1.98	2.16	0.26
Ages (A):						
12 weeks		18	33.46[a]	66.53[a]	28.43[a]	5.04[a]
	± SE		0.69	1.54	1.68	0.20
16 weeks		15	39.88[b]	65.72[a]	30.08[a]	4.19[b]
	± SE		0.76	1.69	1.84	0.22
T × A			ns	ns	ns	ns
RSD[+]			2.95	6.56	7.13	0.86

[+]**RSD** = Residual standard deviation

DM= Dry matter; **CP**= Crude protein; **EE**= Ether extract.

[a,b,] values having different superscripts within each column under each item differ significantly (P<0.05 or P<0.01).

ns= Non-significant (P>0.05). **SE** = Standard error

(1994) reported that meat of rabbits of older age of 140 day had higher fat content and lower water content (i.e. more **DM**) than of 60 day. From the nutritional point of view, it is, therefore, advisable to consume meat from rabbits slaughtered at 12 weeks of age comparable to meat of rabbits slaughtered at 16 weeks of age. This notation was evidenced by findings obtained for interaction between age × treatment of temperature where such interaction was not significant for all traits of meat composition, i.e. there is no carry-over effect from 12 weeks to 16 weeks of age for rabbits raised under high temperature.

Effect of pre-slaughter weight on carcass traits

At 12 and 16 weeks of age, least squares means given in Table 8 show that most carcass traits are greatly affected by the weight of the rabbit before slaughter. Therefore, pre-slaughter weight is considered to be one of

Table 8.Least squares means (+SE) for carcass traits at 12 and 16 weeks of age [@] classified according to different classes of pre-slaughter body weight.

Pre-slaughter weight	HCW (g)	D%	WFP (g)	WHP (g)	LOW (g)	CW (g)	LW (g)	KW (g)	HW (g)	LUW (g)	VW (g)	HEW (g)	FW (g)
At 12 weeks of age:													
<2300 g	1242^{b}	58.6^{a}	232^{b}	432^{b}	342^{b}	216^{b}	81.3^{b}	19.6^{b}	6.6^{a}	14.1^{b}	197^{a}	200^{c}	221^{b}
	± 54	± 1.4	± 11	± 23	± 20	± 10	± 6.9	± 1.4	± 0.7	± 0.8	± 11	± 5.2	± 8.1
2300-2500 g	1321^{b}	55.0^{a}	243^{b}	480^{ab}	330^{b}	241^{a}	84.7^{b}	22.1^{ab}	7.2^{a}	16.9^{a}	206^{a}	222^{b}	274^{a}
	± 54	± 1.5	± 11	± 23	± 21	± 11	± 7.1	± 1.4	± 0.8	± 0.8	± 11	± 5.4	± 8.3
>2500 g	1636^{a}	58.2^{a}	327^{a}	548^{a}	471^{a}	259^{a}	106.0^{a}	26.1^{a}	8.7^{a}	17.4^{a}	191^{a}	241^{a}	288^{a}
	± 62	± 1.6	± 13	± 26	± 24	± 12	± 8.0	± 1.6	± 0.8	± 0.9	±13	± 6.1	± 9.4
RSD[+]	121.5	3.24	25.5	51.6	46.4	23.6	15.7	3.11	1.68	1.74	25.6	11.9	18.4
At 16 weeks of age:													
3200-3400 g	1644^{a}	56.5^{a}	289^{a}	541^{a}	484^{a}	274^{a}	82.5^{a}	24.3^{a}	6.4^{a}	16.8^{a}	195^{a}	257^{a}	337^{a}
	± 47	± 0.8	± 10.3	± 22	± 32	± 17	± 7.4	± 3.8	± 0.4	± 2.0	± 13	± 7.2	± 14
3400-3600 g	2019^{b}	55.3^{a}	353^{b}	646^{b}	496^{a}	450^{b}	106.2^{b}	26.7^{a}	10.4^{b}	20.4^{a}	249^{b}	306^{b}	438^{b}
	± 45	± 0.7	± 9.8	± 21	± 30	± 16	± 7.1	± 3.7	± 0.4	± 1.9	± 12	± 6.8	± 14
RSD[+]	106.7	1.77	23.3	49.2	71.9	39.2	16.9	8.75	0.96	4.64	28.9	16.2	33.0

[+] RSD = Residual standard deviation

[@] Traits as defined in Table 5.

[a,b] Values having different superscripts within each column differ significantly ($P<0.05$).

SE = Standard error

the most important factors affecting carcass traits in rabbits. Rao *et al.* (1978), Ristic *et al.* (1988), Maertens and De Groote (1992), Ristic and Zimmermann (1992) and Szendro *et al.* (1996) have also reported the effect of pre-slaughter body weight on carcass traits. As pre-slaughter weight increases by a category of 200 grams, the edible parts (**WFP**, **WHP**, **LOW**, **CW**, **LW**, **KW** and **HEW**) and the non-edible ones (**LUW** at 12 weeks, **VW** at 16 weeks) were also increased (Table 8).

Carcass traits of 12 weeks vs. 16 weeks of age:

For rabbits slaughtered at 12 weeks of age, the increasing rates in different carcass traits of the category with high pre-slaughter weight (of >2500 grams) compared to the category with low pre-slaughter weight (of <2300 grams) were 31.7% for **HCW**, 41.0% for **WFP**, 26.8% for **WHP**, 37.7% for **LOW**, 20.0% for **CW**, 30.4% for **LW**, 33.2% for **KW**, 31.8% for **HW**, 23.4% for **LUW**, -3.0% for **VW**, 20.5% for **HEW** and 30.3% for **FW** (Table 8). The respective rates of increase in the different carcass traits at 16 weeks of age recorded by the category of 3200-3400 grams compared to the category of 3400-3600 grams were 22.8% for **HCW**, 22.1% for **WFP**, 19.4% for **WHP**, 2.5% for **LOW**, 64.2% for **CW**, 28.5% for **LW**, 9.9% for **KW**, 62.5% for **HW**, 21.4% for **LUW**, 27.7% for **VW**, 19.1% for **HEW** and 30.0% for **FW**. Szendro *et al.* (1996) reported that the rates of change in carcass traits in different categories of pre-slaughter weights were 45% for **HCW**; 45-55% for **KW + HW + LUW**, **WFP** and **WHP**; 23% for **HEW**; and 65-79% for **FW**, **LW** and **LOW**. The above mentioned figures indicate that the rates of increase in carcass performance will be better at the age of 12 weeks than at 16 weeks. Therefore, it is advisable for the commercial rabbit producers to slaughter their rabbits at an earlier age of 12 weeks than at later age of 16 weeks. Rao *et al.* (1978) and Szendro *et al.* (1996) recorded a similar conclusion. On the contrary, Deltoro and Lopez (1986) did not detect any significant change in carcass traits from the age of 11 weeks up to 20 weeks; even dressing percentage decreased during these weeks.

At both ages of the study, effects of interactions between ambient temperature and pre-slaughter weight were not significant for all carcass traits except **CW** at both ages (Table 5). Therefore, any carcass trait resulted from pre-slaughter weight of a certain age (12 or 16 weeks) for rabbits raised in a definite temperature may be of little advantage.

CONCLUSIONS

(1) Results of the present study conclude that raising rabbits at high temperature (32^{0}C) lead to a reduction in live body weights and gains in weights, feed intake and feed conversion which all in turn reduced somewhat the economic profitability of raising Californian rabbits in adverse environment.

(2) Carcasses of heat-stressed rabbits are characterized by higher lean meat content (i.e. more protein) and less fat contents comparable to rabbits raised under normal and moderate environmental temperatures.

(3) It may be preferable to use meat of rabbits of 12 weeks instead of meat at 16 weeks since there was significant more fat deposition in carcasses at 16 weeks of age compared to 12 weeks. Also, the present results indicated that it is preferable, to slaughter rabbits exposed to high temperature at an earlier age of 12 weeks instead of later age at 16 weeks.

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REFERENCES

Abou-Ashour, A.M. and Ahmed, B.M. (1986). Effect of dietary fiber levels on digestibility, performance and cecal microbial activity in growing rabbits. *World Review of Animal Production,* **22** (4): 51-54.

A.O.A.C (1990). Official methods of analysis .(15th Edition). Association of Official Analytical Chemists. Arlington, VA.

Bellier, R. and Gidenne, T. (1996). Consequences of reduced fiber intake on digestion, rate of passage and cecal microbial activity in the young rabbit. *British Journal of Nutrition* **75**: 353-363.

Bieniek, J. Dorozynska, D. Stalinski, Z. and Kolczak, T. (1994). Studies on meat production from rabbits. 2. Effect of age on meat quality. *Prace I Materialy Zootechniczne,* 46: 65-73.

Blasco, A. Ouhayoun, J. and Masoero, G. (1993). Harmonization of criteria and terminology in rabbit meat research. *World Rabbit Science,* 1(1): 3-10.

Champe, K. A. and Maurice, D.V. (1983). Response of early weaned rabbits to source and level of dietary fiber. *Journal of Animal Science,* **56:** 1105-1114.

Chiericato, G.M., Balioni, L.. and Rizzi, C. (1992). The effect of environmental temperature on the performance of growing rabbits. *Journal of Applied Rabbit Research,* **15:** 723-731.

Chiericato, G.M., Rizzi, C. and Rostellato, V. (1993). Effect of genotype and environmental temperature on the performance of the young meat rabbit. *World Rabbit Science,* **1**(3): 119-125.

Deltoro, J. and Lopez, A.M. (1986). Development of commercial characteristics of rabbit carcass during growth. *Livestock Production Science,* **15**: 271-283.

Fuquary, J. W. (1981). Heat stress as it affects animal production. *Journal of Animal Science,* **52**(1): 164-174.

Garcia, J., de Blas, J.C., Carabano, R. and Garcia, P. (1995). Effect of type of lucerne hay on cecal fermentation and nitrogen contribution through cecotrophy in rabbits. *Reproduction, Nutrition and Development,* **35**: 267-275.

Gidenne, T. (1996). Nutritional and ontogenic factors affecting rabbit caeco-colic digestive physiology. *6th World Rabbit Congres,* 1: 13-28 Toulouse, France, July,1996.

Hoover, W.H. and Heitmann, R.N. (1972). Effects of dietary fiber levels on weight gain, cecal volume and volatile fatty acid production in rabbits. *Journal of Nutrition* **102**: 375-379.

Kalogen, U.A. (1985). *Rabbits Feeding* (In Russian). 112 p., Agropomozdat, Moscow.

Lukefahr, S., Hohenboken, W.D., Cheeke, P.R. and Patton, N.M. (1983). Appraisal of nine genetic groups of rabbits for carcass and lean yield traits. *Journal of Animal Science,* **57**(4): 899-907.

Lukefahr, S.D., Nwosu, C.V. and Rao, D.R. (1989). Cholesterol-level of rabbit meat and trait relationships among growth, carcass and lean yield performances. *Journal of Animal Science,* **67:** 2009-2017.

Maertens, L. and de Groote, G. (1992). Study of the influence of slaughter weight on carcass traits and carcass composition of broiler rabbits. *Revue de L'Agriculture,* **45**(1): 59-70.

Marai, F.M., Habeeb, A.A.M., El-Sayiad, GH.A. and Nessem, M.Z. (1994). Growth performance and physiological response of New Zealand White and California rabbits under hot summer condition of Egypt. *First International Conference on Rabbit Production in Hot Climates.* 2: 619-625, Cairo, Egypt, 6-8 Sept. 1994.

Ozimba, C.E. and Lukefahr, S.D. (1990). Evaluation of purebred and crossbred rabbits for carcass merit. *Journal of Applied Rabbit Research*, **13:** 193-198.

Perez, J.M., Fortun-lamothe, L. and Lebas, F. (1996). Comparative digestibility of nutrients in growing rabbits and breeding does. *6th World Rabbit Congress,* **1:** 267-270 *Toulouse, France, July 1996.*

Perez, J.M., Lebas, F., Gidenne, T., Maertens, L., Xiccato, G., Parigi-bini, R., Dallezotte, A., Cossu, M.E., Carazzolo, A., Villamide, M.J., Carabano, R., Fraga, M.J., Ramos, M.A., Cervera, C., Blas, E., Fernandez, J., Falcao, E., Cunha, L.and Bengala Freire, J. (1995). European reference method for in vivo determination of diet digestibility in rabbits. *World Rabbit Science* **3:** 41-43.

Pla, M. (1998). Carcass and meat quality of growing rabbits under high ambient temperature using high fat diets. *2nd* International Conference on Rabbit Production in Hot Climates. Adana, Turkey, 7-9 September, 1998.

Rao, D.R., Chen, C.P., Sunki, G.R. and Johnson, W.M. (1978). Effect of weaning and slaughter ages on rabbit meat production. 2. Carcass quality and composition. *Journal of Animal Science,* **46**(3): 578-583.

Ristic, M., Schlolaut, W. and Lange, K. (1988). Influence of final fattening weight on the carcass value and meat quality of young fattening rabbits. *4th World Rabbit Congress, 2: 196-208, Budapest,* 10-14 October, 1988.

Ristic, M. and Zimmermann, E. (1992). Slaughter value of young rabbits from fattening hybrids and pure breeding animals. *Journal of Applied Rabbit Research,* **15**: 827-831.

Sandford, J. C. (1992). Notes on the history of the rabbit. *Journal of Applied Rabbit Research,* **15:**1-28.

SAS. (1996). *SAS' Procedure Guide.* Version 6.12 Edition. SAS Institute INC., Cary, NC, USA.

Skrivanova, V., Marounek, M., Skrivan, M. and Knizek, J. (1998) Effect of temperature on growth, feed efficiency and mortality of rabbits. *2nd International Conference on Rabbit Production in Hot Climate.* Adana, Turkey, 7-9 September, 1998.

Stephan, E. (1980). The influence of environmental temperature on meat rabbits of different breeds. *2nd World Rabbit Congress, 1: 399-409 Cunicola, Barcelona. Spain.*

Struklec, M., Kermauner, A. and Marinsek Logar, R. (1994). The effect of corn, barley or oats on digestion process and production parameters of growing rabbits. *Znan. Prak. Poljoper. Tehnol.*, **24:** 128-135.

Szendro, Z. S., Papp, Z. and Kustos, K. (1998). Effect of environmental temperature and restricted feeding on production of rabbit does. *2nd International Conference on Rabbit Production in Hot Climates.* Adana, Turkey, 7-9 September, 1998.

Szendro, Z. S., Radnai, M. I., Biro-Nemeth, E., Romvari, R. and Milisits, G. (1996). The effect of live weight on the carcass traits of rabbits between 2.2 and 3.5 kg. *6th World Rabbit Congress,* 3:263-267, *Toulouse, France, July 1996.*

Yamani, K. A. and Farghally, H. M. (1994). Adaptability of rabbits to the hot climate. *First International Conference on Rabbit Production in Hot Climates.* 1: 65-69, *Cairo, Egypt. 6-8 September, 1994.*