Effects of Dietary Intake Level and Seasonal Ambient Temperature on Growth Rate in Growing Najdi Lambs

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Abstract. Twenty-four Najdi ram lambs were utilized to study the effect of dietary intake level and body weight on performance and core body temperature under the prevailing winter and summer months of Saudi Arabia. Each lamb was implanted with telemetric temperature transmitter to monitor the changes in core temperature. Lambs within each season (12 lambs) were randomly allocated to three dietary intake levels with four lambs per level; the dietary intake levels were: low, 55; medium, 68 and high, 81 g DM per $w^{0.75}$.day. Feeding trials were executed when the lambs attained 25-, 35- and 45-kg average body weight; all lambs were individually fed throughout the 3 weeks of feeding trials. There was no significant (P>0.05) effect of season on the performance of 25-kg lambs. When the body weight of winter-raised lambs increased to 35 kg, lambs fed medium and high levels of DMI gained 4.6 and 22.9% more (P<0.05) average daily weight and had 6.3 and 17.2% less feed to gain ratio (P<0.05), respectively, than those lambs in summer months. Winter-raised lambs fed low, medium and high levels of DMI grew 5, 35.1 and 31.3% faster (P<0.05) and were 6.4, 25.5 and 23.7% more efficient (P<0.05) in converting feed into gain, respectively, than those comparable 45-kg lambs in summer months. Generally, increasing the level of daily DMI were coincided with significant increases (P<0.05) in ADG and feed efficiency in all studied weight categories. Average core body temperatures were elevated (P<0.05) by 0.19, 0.12 and 0.13°C in 25-, 35- and 45-kg lambs subjected to summer environments, respectively, than those in winter months. Increasing the level of dietary intake was accompanied by parallel increases (P<0.05) in core body temperature in all weight categories of lambs.

Introduction

Sheep have been raised in Saudi Arabia for several thousand years and among those breeds that have demonstrated good adaptation to local semi-arid weather is Najdi. The Najdi, which is the most popular and predominant breed of the central region of Saudi Arabia, belongs to the fat-tailed and non-seasonal group of sheep; animals are of small body size and have a black coarse fleece that grows to 15 cm (Abouheif and Alsobayel, 1982). Adaptation to the heat stress is likely to have resulted in enhanced thermoregulatory mechanisms of heat loss at the expense of mechanisms for heat conservation (Mader et al., 2002). Several articles have reported that the exposure of livestock to elevated climatic temperatures reduced voluntary feed intake (Ames and Brink, 1977; Alamer and Al-hozab, 2004; Maurya et al., 2004) and increased maintenance requirements (Blaxter and Wainman, 1961). Reduced feed intake results in less essential nutrients and metabolizable energy being consumed. This consequence may be deleterious particularly to the performance of ruminants consuming low energy and fibrous diets (Beede and Collier, 1986). On the other hand, White et al. (1992) and Can et al. (2004) found that the more digestible the diet fed to a thermal-stressed animal the smaller will be the rate and extent of reduction in feed consumption and performance. Reducing ME intake through feed restriction could lower heat production and enhance feed conversion (Purwanto et al., 1990).

Many physiological responses to excessive heat load are strategies for maintaining normal core body temperature. Small upward shifts in core temperature have profound effects on tissues and neuro-endocrine functions, which in turn reduce animal performance (Finch, 1986). However, an understanding of the control of body temperature in local Najdi lambs under the prevailing heat stress conditions, and the relationship of this to performance must come from an approach in which the lambs are viewed in relation to both its thermal and nutritive environments. In this study, we related seasonal ambient temperature, body weight and DMI level to lamb performance and its core body temperature.

Materials and Methods

A total of 24 Najdi ram lambs of the same origin were utilized to study the effect of dietary intake level and body weight on lambs performance and core body temperature under the prevailing winter (19.6°C, 39% RH and 67 Temperature-Humidity Index; (THI) and summer months (37°C, 24% RH and 82 THI) of Saudi Arabia. All lambs were obtained from Al-Watania Agricultural Company; however, one-half of these lambs had been trucked to the Department of Animal Production Experimental Farm, King Saud

University, Riyadh, in December 2003, while the other 12 lambs had been shipped in June 2004, resembling winter and summer groups, respectively. All experimental protocols had been closely repeated in both seasons. Upon arrival, lambs were individually identified, vaccinated, dewormed and vitamin A-D-E injections were given. The lambs were kept in one group and gradually conditioned to the experimental diet for 7 days; diet was offered *ad libitum* and orts were weighed every two days to determine their feeding capacity. The diet was prepared as a loose whole mixed diet consisting of 75% concentrate and 25% roughage; the ingredients (Table 1) were ground through a 4.76 mm screen and mixed thoroughly in a stainless steel vertical mixer. The ME content of the experimental diet was previously determined (Al-Owaimer et al., 2003). Ambient temperature and relative humidity were monitored continuously at 30-minute intervals using data loggers. Lambs were then individually housed in concrete floored pens in an open-sided building until the termination of the study; each lamb was surgically implanted intraperitoneally with calibrated telemetric temperature transmitters (Mini-Mitter Co. Inc.; Model VHF-T-1; Sun River, Oregon) for monitoring core body temperature at 30- minute intervals throughout the experiment (Al-Haidary, 2005). Average core body temperature (CT) for each lamb was calculated out of three readings a day and throughout the 3-week experimental trial, at 08:00, 14:00 and 20:00 h local time. These times were chosen because they correspond to the normal daily rhythm of body temperature in sheep maintained under heat stress conditions (Al-Haidary, 2000). Fifteen days later,the lambs weights were recorded every third day until they attained an average of 25 kg; thereafter, the lambs were randomly allocated to three dietary intake levels with four lambs per level. The dietary intake levels were: low (L), 55; medium (M), 68 and high (H), 81 g DM per $w^{0.75}$.day. During the three weeks of feeding study, each lamb was weighed weekly after being held from feed for 8 hours. The daily allocated amount of feed of each lamb was adjusted according to his weight and feeding level after each weighing; feed was offered once daily at 07:00 hours. Feed refusals were removed, weighed, sampled for DM determination.

Upon the termination of 25-kg lambs feeding trial, all lambs were fed a common dietary intake level of 68 g DM. $w^{0.75}$.day until they attained an average body weight of 35 kg; the lambs were then randomly re-allotted to the three dietary intake levels. All experimental protocol and procedures that underwent in the 25-kg lambs trial were closely executed in the 35-kg and further in the 45-kg lambs feeding trials. Throughout the feeding trials, feed consumption (DMI) and average core body temperature (CT) data were recorded daily and fasted lamb weight was recorded weekly. Average values of DMI, ADG, CT and feed/gain ratio were analyzed separately for each studied body weight (25-, 35- and 45-kg) using the general linear models procedures (SAS, 1986), with dietary intake level (55, 68 and 81 g DM. $w^{0.75}$.day) and season (winter and summer) included in the model. Means were separated by the least significant difference procedure.

Results

The effects of season and dietary intake level on the performance of 25-kg lambs are presented in Table 2. Despite that there was no effect of the season on lambs performance (P>0.05), the lambs fed high DMI in summer months had 7.8 and 7.3% lower ADG and gain efficiency, respectively, than those comparable lambs raised in winter months under the same feeding level. the Lambs offered low DMI gained less body weight (P<0.05) and converted feed into body gain less efficiently (P<0.05) than those offered higher amounts of daily DMI. Average core body temperature was lower (P<0.05) in winter-raised lambs compared with lambs in summer months. The Increasing level of dietary intake was accompanied by parallel increases (P<0.05) in core body temperature.

When the body weight of winter-raised lambs increased to 35 kg (Table 3), lambs fed M and H levels of DMI gained 4.6 and 22.9% more (P<0.05) average daily weight and had 6.3 and 17.2% less feed to gain ratio (P<0.05), respectively, than those lambs in summer months. Generally, increasing the daily DM intakes were coincided with significant increases (P<0.05) in ADG and feed efficiency. Average core body temperature was elevated (P<0.05) by approximately 0.12°C in lambs subjected to summer environment. Lambs consumed H level of DMI had an average of 0.05°C (P>0.05) and 0.15°C (P<0.05) higher core body temperature than those lambs consumed M and L levels, respectively.

Feed intake, ADG and gain efficiency for the 45-kg lambs during summer and winter months and for the different feeding levels are shown in Table 4. Increasing the level of daily DMI significantly improved ($P<0.05$) the ADG and feed efficiency; however, winter-raised lambs fed L, M and H levels of DMI grew 5, 35.1 and 31.3% faster ($P<0.05$) and were 6.4, 25.5 and 23.7% more efficient ($P<0.05$) in converting feed into gain, respectively, than those summer-raised lambs. Although lambs in winter months had lower ($P<0.05$) average core body temperature, they exhibited noticeable increases in temperature with increased DMI than comparable lambs in summer months (0.34°C vs. 0.03°C).

When performance traits and core body temperature regressed on DMI (Table 5), it is obvious that ADG increased linearly ($P<0.05$) with the increased level of intake from 55 to 81 g.$W^{0.75}$.day for all lambs in different weight categories; however, the differences between winter-growth and summer-growth lines were progressively grew wider with either increased level of DMI or increased body weight (fig. 1).

Discussion

The experimental lambs were maintained at an ambient temperature ranging from 16 to 23°C and from 35 to 38°C during winter and summer months, respectively. The average daily temperature and average daily temperature-humidity index (THI) during the summer months of the study were 17.4°C and 15 higher than in winter months, respectively. Sheep will survive acute periods of 79-88 THI (NRC, 1981), but the critical THI above which production and reproduction are depressed in dairy cows (Johnson and Vanjonack, 1976) and growing lambs (NRC, 1981) were 71 and 76, respectively. The average daily THI during the summer months of this study exceeded 79 for all days; therefore, it is reasonable to assume that the experimental lambs were withstanding extreme heat stress. On the other hand, average daily temperature during winter months of the study (19.6°C) was within the thermal neutral zone of growing lambs (Bianca, 1970; Al-Haidary, 2004). Moose et al. (1969) and Ames and Brink (1977) suggested that the minimum metabolic heat production and maximum weight gain estimates of thermal neutral zone for similar lambs weights ranged from 15 to 25°C.

Animals typically respond to the heat stress of high temperature by reducing DMI and performances; however, the environmental temperature at which feed consumption begins to decline is influenced by dietary composition, body weight and acclimatization (Beede and Collier, 1986). In this study, high ambient temperature during the summer months did not reduce the performance of 25-kg lambs. This can be explained because the negative effect of heat stress would likely become less significant when the experimental diet of high potential metabolizable energy (2.73 Mcal/kg) was fed to lambs of lighter body weights. Moreover, Beede and Collier (1986), White et al. (1992) and Can et al. (2004) suggested that the more digestible the diet fed to a heat-stressed animal the smaller will be the rate and extent of reduction in feed consumption and performance. Local black Najdi breed is well adapted to the prevailing summer conditions of Saudi Arabia. Several researchers reported that adapted animals of lighter weights are less influenced by summer heat stress than for unadapted animals (Johnson et al., 1958; Colditz and Kellaway, 1972). As the summer-fed Najdi lambs grew heavier in weights (35- and 45-kg), DMI and the corresponding performances were reduced significantly ($p<0.05$) as compared to winter–fed lambs, indicating that heavier Najdi lambs are more sensitive to heat stress than lighter lambs. Reduced ADG in heat-stressed lambs was expected because maintenance requirement for energy increases while energy intake declines (Ames and Brink, 1977). Reduced feed intake results in less essential nutrients and metabolizable energy being consumed; this consequence may be deleterious to lamb performance. Actual DM consumption in the summer-raised lambs that offered H level of intake decreased to approximately 91% of their offered daily DM in comparison to 97.3 and 98.6% in 25-kg and 35-kg lambs, respectively. Similar results were reported by Mangold et al. (1967) who found that finishing pigs (70-100 kg) showed greater reduction in both intake and gain in a 39°C environment than did growing (45-70 kg) pigs. Heavier lambs are usually fatter and have a lower upper critical temperature (NRC, 1981). The reduction of DMI in heavier lambs exposed to high ambient environmental temperature is probably resulting from attempts to stabilize the generated heat load from ruminal fermentation and body metabolism in order to maintain heat balance.

There is evidence that a reduction in DM intake is followed by a reduction in metabolic rate (Purwanto et al., 1990). The lowered intensity of heat production is due to decreased maintenance heat production. A further effect of decreased DMI is a reduction in core body temperature (Finch, 1986; Turner and Taylor, 1983). Regardless of the studied season, decreasing the DMI in all studied weight categories of lambs was accompanied by parallel significant decreases in core body temperatures. This was in accordance with the results obtained by Mader et al. (2002) who found that steers fed on restricted DMI had the lowest numerical tympanic and rectal temperatures than high energy fed steers. Core body temperature measured in the summer was consistently higher than that measured in winter months for all levels of DMI and studied body weights. This difference is a natural consequence of the seasonal rhythm of body temperature previously described in a variety of species, including sheep (Da Silva and Minomo, 1995; Mohr and Krzywanek, 1995). The noticeable small upward increases in core body temperature have profound effects on the physiological responses of lambs, which in turn reduce the ADG and offset gain efficiency. Similar result was reported by Umphrey et al. (2001) who found that DMI in dairy cows living in the southern United States is negatively correlated with rectal temperature. This increase in core body temperature may be a specific adaptation to hot ambient temperatures, since it reduces the metabolic effort needed for homeothermy.

The results of the previous study indicate that it may be difficult through the manipulation of feed intake to achieve both efficient thermoregulation and high inherent productivity under the prevailing summer environmental conditions of Saudi Arabia. The potential to attain high ADG appears to be handicapped in the process of gaining improved thermoregulatory abilities. However, further investigations are required to elucidate the degree of compromise in inherent ADG resulting from such intake manipulation procedures in growing Najdi lambs.

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Table 1. Ingredients and chemical composition of experimental diet.

Item	DM basis, %
Ingredients:	
Alfalfa hay	25.7
Maize	38.6
Barley	23.8
Soybean meal	9.1
Mineral supplement[a]	2.6
Trace mineral and vitamin premix[b]	0.2
Chemical composition:	
CP	15.25
CF	8.16
ADF	14.98
NDF	49.42
NFE	67.77
EE	2.44
Ash	6.04
Ca	0.81
P	0.45
ME, Mcal/kg	2.73

[a]Supplement composition: 30% sodium bicarbonate; 30% ground limestone; 20% dicalcium phosphate; 20% sodium chloride.

[b]Contained per kg of mineral and vitamin premix: CoSO4, 0.30g; CuSO4, 20.1g; FeSO4, 10.0g; ZnO, 50.0g; MnSO4, 40.2g; KI, 0.75g; NaCL, 2.81g; vitamin A, 500,000 IU; vitamin D, 500,000 IU and vitamin E, 10,000 IU.

Table 2. Effect of dietary intake level and seasonal environment on the performance of 25-kg lambs.

Treatment[a]	Body weight, kg Initial	Final	DMI g/w$^{.75}$	ADG g/d	Feed/gain g/g	CT[b] °C
Winter						
L	25.7	27.7[c]	51.87[c]	95[c]	6.41[e]	38.96[c]
M	25.3	29.7[d]	68.00[d]	211[d]	3.89[d]	39.12[d]
H	25.4	31.6[e]	78.67[e]	295[f]	3.29[c]	39.18[de]
Summer						
L	25.9	28.0[c]	53.13[c]	98[c]	6.42[e]	38.99[c]
M	25.9	30.3[de]	66.78[d]	206[d]	3.96[d]	39.28[e]
H	25.6	31.3[de]	78.80[e]	272[e]	3.53[c]	39.58[f]
SEM	0.41	0.84	4.91	4.22	0.16	0.061
Season effect						
Winter	25.4	29.7	66.28	200	4.53	39.09[c]
Summer	25.8	29.9	66.00	192	4.64	39.28[d]
DMI effects						
L	25.8	27.8[c]	52.45[c]	97[c]	6.41[e]	38.98[c]
M	25.6	30.0[d]	67.54[d]	209[d]	3.94[d]	39.20[d]
H	25.5	31.5[e]	78.33[e]	284[e]	3.42[c]	39.38[e]

[a]There were four lambs per season x DMI treatment; low (L), medium (M) and high (H) were the levels of dietary intake that offering lambs with 55, 68 and 81 g DM/w^{075}/d, respectively; final body weight was measured after 3 weeks on the designated dietary level.
[b]Average core body temperature.
[c,d,e,f]Means in the same column within an effect bearing different superscripts differ ($p<0.05$).

Table 3. Effect of dietary intake level and seasonal environment on the performance of 35-kg lambs.

Treatment[a]	Body weight, kg Initial	Body weight, kg Final	DMI $g/w^{.75}$	ADG g/d	Feed/gain g/g	CT[b] °C
Winter						
L	35.2	37.1[c]	53.73[c]	92[c]	8.61[f]	38.99[c]
M	35.4	39.7[d]	65.85[d]	203[e]	4.92[d]	39.20[d]
H	35.2	41.5[e]	80.84[e]	301[g]	4.14[c]	39.15[d]
Summer						
L	35.6	37.6[c]	54.00[c]	93[c]	8.63[f]	39.18[d]
M	35.6	39.7[d]	67.02[d]	194[d]	5.25[e]	39.18[d]
H	35.5	40.6[de]	79.90[e]	245[f]	5.00[de]	39.33[e]
SEM	0.53	1.02	4.15	4.05	0.18	0.062
Season effects						
Winter	35.2	39.4	66.81	199[d]	5.89[d]	39.11[c]
Summer	35.6	39.3	66.97	177[c]	6.29[c]	39.23[d]
DMI effects						
L	35.4	37.3[c]	53.87[c]	93[c]	8.62[e]	39.09[c]
M	35.5	39.7[d]	66.44[d]	199[d]	5.06[d]	39.19[d]
H	35.3	41.1[d]	80.36[e]	273[e]	4.57[c]	39.24[d]

[a]There were four lambs per season x DMI treatment; low (L), medium (M) and high (H) were the levels of dietary intake that offering lambs with 55, 68 and 81 g DM/w^{075}/day, respectively; final body weight was measured after 3 weeks on the designated dietary level.

[b]Average core body temperature.

[c,d,e,f,g]Means in the same column within an effect bearing different superscripts differ ($p<0.05$).

Table 4. Effect of dietary intake level and seasonal environment on the performance of 45-kg lambs.

Treatment[a]	Body weight, kg Initial	Final	DMI $g/w^{.75}$	ADG g/d	Feed/gain g/g	CT[b] °C
Winter						
L	45.4	47.6[c]	52.52[c]	106[c]	8.65[de]	39.00[c]
M	44.9	49.3[d]	66.31[d]	208[e]	5.48[c]	39.18[d]
H	45.0	51.1[e]	78.93[f]	294[g]	4.53[c]	39.34[e]
Summer						
L	45.0	47.2[c]	52.74[c]	101[c]	9.24[e]	39.29[ef]
M	45.1	48.4[cd]	63.42[d]	154[d]	7.36[d]	39.22[df]
H	44.9	49.7[d]	73.73[e]	224[f]	5.94[c]	39.32[e]
SEM	1.06	0.81	3.09	6.84	1.10	0.060
Season effects						
Winter	45.1	49.3	65.92[d]	203[d]	6.22	39.15[c]
Summer	45.0	48.4	63.30[c]	160[c]	7.51	39.28[d]
DMI effects						
L	45.2	47.4[c]	52.63[c]	104[c]	8.95[e]	39.15[c]
M	45.0	48.8[c]	64.87[d]	181[d]	6.42[d]	39.20[c]
H	45.0	50.4[d]	76.33[e]	259[e]	5.24[c]	39.33[d]

[a]There were four lambs per season x DMI treatment; low (L), medium (M) and high (H) were the levels of dietary intake that offering lambs with 55, 68 and 81 g DM/w^{075}/day, respectively; final body weight was measured after 3 weeks on the designated dietary level.

[b]Average core body temperature.

[c,d,e,f,g]Means in the same column within an effect bearing different superscripts differ ($p<0.05$).

Table 5. Estimates of linear parameters for ADG, feed/gain ratio and core body temperature regressed on various dietary intake levels during winter and summer seasons.

	Winter		Summer	
Trait	Intercept	b[a]	Intercept	b[a]
25-kg lambs				
ADG, g/d	-293.21	7.455*	-271.78	7.030*
Feed/gain ratio	12.45	-0.120	12.45	-0.118
Core temperature, °C	38.53	0.008	37.72	0.024
35-kg lambs				
ADG, g/d	-313.03	7.659*	-216.05	5.874*
Feed/gain ratio	16.61	-0.161	15.69	-0.140
Core temperature, °C	38.74	0.006	38.84	0.006
45-kg lambs				
ADG, g/d	-346.07	8.767*	-213.93	5.900*
Feed/gain ratio	18.44	-0.195	17.47	-0.157*
Core temperature, °C	38.18	0.016*	39.19	0.001

[a]Regression coefficient.
*$P<0.05$.

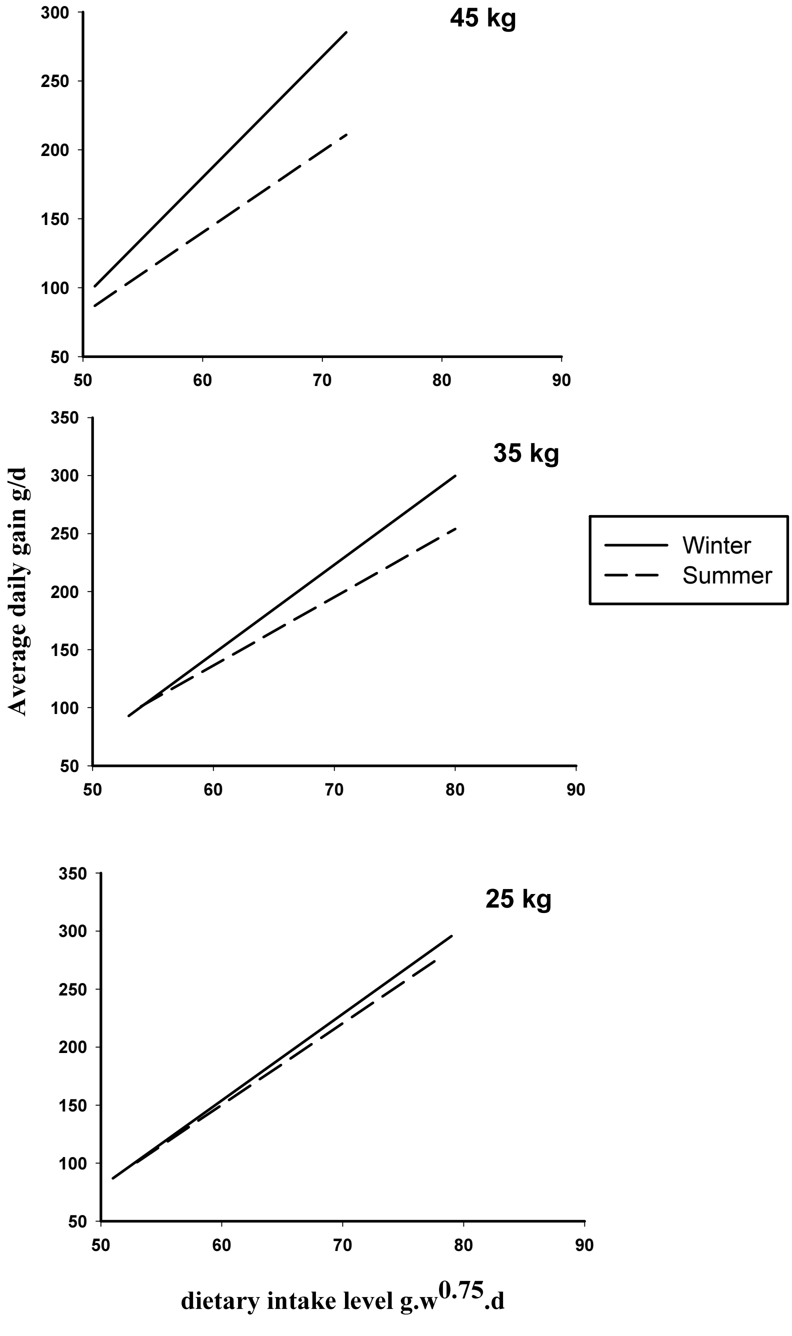

Fig 1. Relation between increase in average daily gain (g/d) and the amount of dietary intake level (g.w $^{0.75}$ .d) during winter and summer seasons for all studied weight categories of Najdi lambs.

تأثير كمية الغذاء ودرجة الحرارة الفصلية على معدل نمو الحملان النجدي النامية

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الكلمات المفتاحية: الأغنام النجدي ، الغذاء المأكول، درجة حرارة الجو ، معدل النمو

ملخص البحث. استخدم في هذه الدراسة 24 حملاً نجدياً لدراسة تأثير مستوى الغذاء المأكول ووزن الجسم على جودة الإنتاج ودرجة حرارة الجسم الداخلية خلال أشهر الشتاء والصيف في المملكة العربية السعودية. تم وضع مجسات قياس درجة الحرارة داخل تجويف كل حمل وذلك لمراقبة التغير في درجة حرارة الجسم الداخلية، ووزعت الحملان عشوائياً (12 حملاً لكل موسم) إلى ثلاث مجاميع طبقاً لمستوى الغذاء المأكول (منخفض 55 جم/كجم $^{0.75}$ يوميا، متوسط 68 جم/كجم $^{0.75}$ يومياً ، عالي 81 جم/كجم $^{0.75}$ يوميا). نفذت تجربة التغذية عندما وصلت الحملان إلى وزن جسم 25، و35 و45 كجم، حيث غذيت جميع الحملان فرديا خلال فترة الـ 3 أسابيع التجريبية. أوضحت النتائج أنه لا يوجد تأثير معنوي (P<0.05) للفصل الموسمي على جودة إنتاج الحملان عند وزن 25 كجم، وعندما ارتفع وزن الجسم إلى 35 كجم لوحظ أن الحملان المرباة خلال فصل الشتاء وتغذت على مستوى متوسط وعالي من المادة الجافة اكتسبت وزن جسم يومي بمعدل أعلى (P<0.05) بحوالي 4.6 و 22.9% واستهلكت 6.3 و 17.2% مادة غذائية أقل (P<0.05) لكل وحدة نمو مكتسب على التوالي عند مقارنتها بالحملان التي ربيت خلال فصل الصيف. وقد لوحظ أن الحملان ذات وزن 45 كجم والمغذاة خلال فصل الشتاء على مستويات منخفضة، ومتوسطة وعالية نمت بمعدل 5 ، و35.1 و31.3% أسرع (P<0.05) وكانت أفضل (P<0.05) في تحويل الغذاء إلى وزن بحوالي 6.4 ، و25.5 ، و23.7% على التوالي بالمقارنة مع حملان فصل الصيف. وبصورة عامة وجد أن زيادة مستوى الغذاء الجاف المأكول يومياً يصاحبه ارتفاع معنوي (P<0.05) في معدل الزيادة اليومية لوزن الجسم والكفاءة الغذائية التحويلية لجميع الأوزان في التجربة. وجد أن متوسط درجة حرارة الجسم الداخلية للحملان ارتفع (P<0.05) بمعدل 0.19 ، و0.12 و 0.13 درجة خلال أشهر الشتاء بالمقارنة مع أشهر الصيف، وذلك للحملان التي يزن جسمها 25، و35 و45 كجم على التوالي، ولوحظ أيضاً أن الزيادة في كمية الغذاء اليومي المأكول صوحبت بزيادة (P<0.05) موازية في درجة حرارة الجسم الداخلي لجميع الأوزان التي تحت دراستها.