

EFFECT OF HEAT STRESS ON PROTEIN REQUIREMENTS FOR MAINTENANCE OF EGYPTIAN NUBIAN GOATS

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SUMMARY

This study was conducted to determine protein requirements for maintenance (RCP) of Egyptian Nubian goats under 25°C and 35°C environmental temperature. Protein requirements for maintenance of goats were determined under the two environmental temperatures from nitrogen balance data applying statistical, factorial and graphical methods. Goats were fed four rations differed in dietary protein concentrations (9.38, 11.81, 13.22 and 14.74 %).

Results indicated that RCP calculated by any method was lower for goats under 35°C than those under 25°C by about 25%; averaging 5.63 g/Kg $W^{0.075}$ for goats under 25°C and 4.31 g/Kg $W^{0.075}$ for those under 35°C.

Keywords: *goat, protein, maintenance requirement, heat stress*

INTRODUCTION

Protein is the most expensive nutrient in livestock feeding; therefore, it is often a limiting factor of its productivity. (Singh and Sengar, 1970). The maintenance requirement of protein comprises a great amount of daily intake of ruminant rations. The amount of protein needed for maintenance is nearly consisting 40-50% of the total protein intake (NRC, 1985).

Determination of protein for maintenance is influenced by many factors, i.e. animal (age, species, breed, physiological status and activity), diets (composition, energy-protein ratio, level of degradable protein and essential amino acid content), climatic conditions (ambient temperature and relative humidity) and methodology by which protein requirements are determined (El-Bedawy *et al.*, 1998).

The objective of this study is to determine the effect of environmental temperature on nitrogen metabolism and maintenance requirement of protein for Egyptian Nubian goats applying different experimental procedures.

MATERIALS AND METHODS

The effect of heat stress on nitrogen metabolism and protein requirements for maintenance of Egyptian Nubian goats was determined through nitrogen metabolism trial (nitrogen balance trials). Eight Egyptian Nubian goat bucks aged 12 – 18 months with body weight ranging from 25.5 to 36.0 Kg were used in this trial. The bucks were randomly divided into two groups each of four animals. The first group was

maintained under constant 25°C and 60 % relative humidity (RH) while, the second group was kept under constant 35°C and 60 % RH.

The bucks were fed isocaloric rations but differed in crude protein (CP) content, at the level of 2.2% DM of live body weight. The percentage of CP in the experimental rations was 9.83, 11.81, 13.22 and 14.74 for rations 1, 2, 3 and 4, respectively. Ingredient and chemical composition of the experimental rations are presented in Tables (1 and 2). The rations were fed individually in metabolic cages for 21 days as preliminary period followed by 7 days for total collection of feces and urine. Initial and final body weights were recorded for each experiment. Drinking water was available in free choice and daily water consumption was recorded. Feeds were offered once a day at 9:30 h. and residues, if any, were daily collected and weighed to determine daily feed intake. Feces and urine were collected, a 10% sample of the collected feces was sprayed with solution of 10% sulfuric acid and 10% formaldehyde, then oven dried at 60 °C for 24 hours. A composite sample of dry feces for each buck was ground and kept at room temperature for nitrogen determination. Urine was collected in clean stopper plastic bottles each containing 50 ml of 10% sulfuric acid. Daily 10% sample of collected urine was used for nitrogen determination.

Chemical composition of feeds, feces and nitrogen contents of the urine were determined according to the standard methods of A.O.A.C. (1984).

Table 1. Ingredient composition of the experimental rations

Ingredient	IFN	Dietary CP %			
		9.83	11.81	13.22	14.74
Yellow corn	4-02-931	42	35	28	21
Barley grain	4-00-549	21	21	21	21
Soybean meal	5-04-604	3.5	7	10.5	14
Wheat bran	4-05-190	1.75	5.25	8.75	12.25
Rice straw	1-04-077	30	30	30	30
Min. & vit. Premix		1.75	1.75	1.75	1.75

Table 2. Chemical compositions of the experimental rations

Chemical composition	Dietary CP %			
	9.83	11.81	13.22	14.74
Dry matter	90.90	90.90	91.11	91.18
<i>Chemical composition as DM basis</i>				
Organic matter	92.5	93.72	92.22	92.15
Crude protein	9.83	11.81	13.22	14.74
Crude fiber	14.35	14.89	15.04	15.48
Ether extract	1.71	2.02	2.10	1.86
Nitrogen free extract	66.47	65.00	61.96	60.07
Ash	7.50	6.28	7.87	7.85

Quantification of nitrogen requirement for maintenance

Nitrogen balance was calculated by the difference between nitrogen intake and nitrogen outgo in feces and urine. Nitrogen requirement for maintenance was calculated applying statistical, factorial and graphical methods.

Statistical method based on the relationship between nitrogen intake and nitrogen balance as mentioned by Singh and Mudgal (1991) was used to calculate the nitrogen requirements by regression of nitrogen intake (NI) on nitrogen balance (NB), NI as dependent variable (Y) and nitrogen balance (NB) as independent variable (X) for the 16 observations in each group. The general regression formula is

$$Y = a + bx, \text{ then } NI = a + b(NB)$$

At NB = zero (Nitrogen equilibrium), then N requirement = the intercept value

Factorial method was used to determine the nitrogen requirement for maintenance according to the following formula applied by Harris and Mitchell (1941) as suggested by Sengar (1980). N requirement = MFN + EUN/ BV X TD

Endogenous urinary nitrogen (EUN) was calculated by regression of urinary nitrogen (UN) on nitrogen intake (NI) by regression formula:

$$UN = a + b(NI) \text{ when } NI = \text{Zero then } UN = EUN,$$

Metabolic fecal nitrogen (MFN) was calculated by regression of fecal nitrogen (FN) on nitrogen intake (NI) by regression formula

$$FN = a + b(NI) \text{ when } NI = \text{Zero then } FN = MFN$$

Biological value (BV) of protein was calculated according to the following formula (Mitchell, 1924) $BV = [NI - (FN - MFN) - (UN - EUN) / NI - (FN - MFN)] \times 100$

True digestibility (TD) of dietary protein was calculated according to the following formula (Mitchell, 1924). $TD = [NI - (FN - MFN) / NI] \times 100$

Graphical method as described by Majumdar (1960) and Sengar (1980) was applied to determine nitrogen requirement for maintenance. Nitrogen balance values (mg N/Kg W) where plotted on (Y) axis against daily nitrogen intake (mg N/Kg W) on (X) axis for each individual animal. The high points were joined to the lowest point. Lines joining these points were extended to cut the ordinate at three level of NI. The lowest level (a) shows the minimum N intake and the highest level (b) represent the maximum N intake, at nitrogen equilibrium (NB= zero) the average of these two values (a and b) represents the maintenance nitrogen requirement for each individual buck. Values were averaged for 25°C and 35°C groups represent maintenance nitrogen requirement for goats under 25°C and 35°C

2.2. Statistical analysis

Two factors factorial arrangement was used to test the effect of dietary protein and ambient temperature and their interaction using analysis of variance procedure (Proc. ANOVA). Since the interaction between the dietary protein level and environmental temperature was not significant then it was excluded from the model. Duncan's multiple range tests was used to separate mean effects for the dietary protein and ambient temperature and their interaction (SAS, 1999).

The applied model is:

$$Y_{ijk} = \mu + a_i + b_j + e_{ijk}$$

Where,

Y_{ijk} = is the vector of observation;

μ = the overall mean;

a_i = the effect of i^{th} protein level ($i = 1, 2, 3$ and 4);

b_j = the effect of j^{th} temperature ($j = 1$ and 2);
 e_{ijk} = the vector of random error normally and independently distributed with $(0, \sigma^2_e)$.

RESULTS AND DISCUSSION

Effect of dietary protein level and environmental temperature on nutrient digestibilities, water balance and nitrogen balance were determined from nitrogen metabolism trials data. Also, nitrogen requirement was calculated from nitrogen balance data applying different method of calculation.

The mean effects of dietary protein level and environmental temperature on nutrient digestibilities are shown in Table (3). Increasing dietary crude protein from 9.83 % to 11.81% significantly improved the digestibility of DM, CP and CF. However, the digestibility of OM, EE and NFE were not affected. The increase of dietary CP above 11.81 % showed no parallel increase in nutrients digestibility. These results conform with those found by Woods *et al.* (1958) which indicated that the nutrient digestibilities increased as the level of dietary protein increased from 4% to 8% in sheep rations. Similar results were reported by Bunting *et al.* (1987) that dry matter and nitrogen digestibilities increased by increasing CP intake from 12 g to 21g N/day.

The present results of non-significant increase in DM, CP and CF digestibilities by increasing dietary crude protein concentration above 11.81 confirmed the findings of Ahmed and Abdellatif (1995) that increasing dietary CP from 12.8 % to 14.7 % was not associated with an increase in nutrient digestibilities by desert sheep.

Increasing environmental temperature from 25°C to 35°C caused a slight increase in nutrient digestibilities (from 2-3 digestion unites) but, these differences were not statistically significant (Table 3). McDowell *et al.* (1969) reported higher nutrient digestibilities by Holstein cows under 32.2°C than by those under 15.24 °C. Also, Warren *et al.* (1974) found that the digestibilities of crude protein and fiber fractions were higher under 32°C than those under 18°C in Holstein steers. Murad *et al.* (1994) found that feeding high concentrate diets resulted in higher nutrient digestibilities except crude fiber under 35°C but not under 18 °C. It was suggested that the influence of ambient temperature on apparent digestibilities of nutrients depends on diet composition

Increasing dietary crude protein concentrations increased nitrogen intake significantly (Table 4). This result is in agreement with the findings of Helal (2002) who found that nitrogen intake increased by increasing dietary crude protein percentage in Baladi goats.

Increasing nitrogen intake from 9.07 to 11.22 and 12.82 g/h/day did not result in a significant increase in fecal nitrogen being 3.57, 3.65 and 3.58 g/h/day for the three levels of protein respectively. However, fecal nitrogen output of goats on the highest nitrogen protein intake (14.54 g/h/day) was 4.28g/h/day ($p < 0.05$) higher than the other three groups (Table, 4). Increasing nitrogen intake from 9.07 to 11.22 g/h/day ($p < 0.05$) increased urinary nitrogen loss from 4.11 to 6.35 g/h/day, but the increase in nitrogen intake above 11.22g/h/day was not met by a parallel increase in urinary nitrogen loss. Urinary nitrogen was found to be increased by increasing nitrogen intake by goats (Helal, 2002), sheep (El-Bedawy *et al.*, 1998). This result could

suggest that fecal nitrogen loss is less affected by increasing nitrogen intake. In this connection, Aarts *et al.* (1992) reported that the concentration of protein in the diet has a greater impact on urinary excretion than fecal nitrogen excretion.

Table 3. Mean effect of dietary protein level and heat stress on nutrient digestibilities %

Item	Dietary protein, %				SEM	Environmental temperature		SEM
	9.83	11.81	13.22	14.74		25°C	35°C	
	DM	67.36 ^b	71.02 ^a	72.53 ^a		71.28 ^a	1.11	
OM	73.83	77.06	77.08	75.65	1.04	74.98	76.83	0.73
CP	60.06 ^b	67.44 ^a	71.85 ^a	70.68 ^a	1.53	66.23	68.78	1.08
CF	53.89 ^b	64.61 ^a	64.53 ^a	56.48 ^{ab}	3.07	58.26	61.49	2.17
EE	84.01	76.95	80.19	73.96	3.80	77.39	80.17	2.69
NFE	79.86	81.45	81.14	81.86	0.79	80.37	81.79	0.56

^{a,b} Means in the same row within each trait having different superscripts differ ($p < 0.05$)

Table 4. Mean effects of protein level and environmental temperature on nitrogen metabolism in goats

Items	Dietary protein, %				SE	Environmental temperature		SE
	9.83	11.81	13.22	14.74		25°C	35°C	
	<i>g/h/day</i>							
Input	9.07 ^d	11.22 ^c	12.82 ^b	14.54 ^a	0.37	11.77	12.06	0.26
Fecal	3.57 ^b	3.65 ^b	3.58 ^b	4.28 ^a	0.20	3.88	3.66	0.14
Urinary	4.11 ^b	6.35 ^a	6.95 ^a	7.20 ^a	0.48	6.12	6.18	0.34
Output	7.68 ^b	10.00 ^a	10.53 ^a	11.48 ^a	0.51	10.00	9.84	0.36
Balance	1.39 ^b	1.22 ^b	2.29 ^{ab}	3.06 ^a	0.50	1.77	2.22	0.35
<i>mg/h/KgW^{0.75}/day</i>								
Input	731 ^d	890 ^c	994 ^b	1097 ^a	8	927	928	6
Fecal	288 ^{ab}	290 ^{ab}	278 ^b	3231 ^a	14	306	283	10
Urinary	332 ^b	508 ^a	538 ^a	544 ^a	37	483	478	26
Output	620 ^b	798 ^a	816 ^a	867 ^a	37	789	761	26
Balance	111 ^b	92 ^b	178 ^{ab}	230 ^a	38	138	167	26

^{a,b} Means in the same row within each trait having different superscripts differ ($p < 0.05$)

Total nitrogen output ($p < 0.05$) increased from 7.68 to 10.00 g/h/day by increasing nitrogen intake from 9.07 to 11.22 g/h/day (Table,4). The bucks showed comparable high total nitrogen output, however not statistically different at 11.22, 12.82 and 14.54 g/h/day nitrogen intake. Several authors stated that total nitrogen output was increased by increasing dietary protein concentration, in goat (Kurar and Singh, 1982; Chandra and Kurar, 1984 and Helal, 2002), in sheep (Reuben, 1992 and El-Bedawy *et al.*, 1998). The changes in nitrogen output resulted in no significant differences in nitrogen balance of goats consuming 9.07, 11.22 or 12.82 g/h/day being 1.39, 1.22 and 2.29 g/h/day. However, increased dietary nitrogen to 14.54 g/h/day ($p < 0.05$) increased nitrogen balance to 3.06 g/h/day.

Increasing environmental temperature from 25 to 35 °C did not significantly affect nitrogen intake, fecal nitrogen and urinary nitrogen but increased ($p > 0.05$) nitrogen balance from 1.77 to 2.22 g/h/day or from 138 to 167 mg/Kg $W^{0.75}$ /d (Table, 4). Contradicting results were reported for the effect of the environmental temperature on nitrogen balance. Horton and Rodriguez (1997) found that increasing ambient temperature from 15 to 34°C did not affect nitrogen balance in Croix sheep, while Dixon *et al.* (1999) found that increasing ambient temperature from 15 to 40°C decreased nitrogen balance in Merino x Border Leicester crossbred sheep.

Maintenance nitrogen requirement was determined applying statistical, factorial, and graphical methods,

Statistical method

Under 25°C the regression equation was found to be $NI \text{ (g/h/day)} = 11.03 + 0.41 NB \text{ (g/h/day)}$. At nitrogen equilibrium ($NB = 0$), Nitrogen intake will represent nitrogen requirement for maintenance. Thus the nitrogen requirement for goats under 25°C was found to be 5.45 g CP/ Kg $W^{0.75}$ or 3.6 g DCP/Kg $W^{0.75}$ based on protein digestibility = 66.33 % and body weight = 29.5 Kg in average.

Under 35°C the regression equation was found to be $NI \text{ (g/h/d)} = 9.25 + 1.26 NB \text{ (g/h/d)}$ thus the nitrogen requirement for maintenance was found to be 4.48 g CP/ Kg $W^{0.75}$ or 3.1 g DCP/Kg $W^{0.75}$ based on protein digestibility = 69.3 % and body weight = 30.31 Kg in average.

Factorial method

Nitrogen requirement for maintenance was also quantified applying the factorial method using Harris-Mitchell (1941) formula.

Endogenous Urinary nitrogen (EUN)

For goats under 25°C, the correlation coefficient between UN and NI was 0.65, intercept was -187.27 and regression coefficient was 0.72 and regression formula was $UN \text{ (mg/Kg } W^{0.75}) = -187.27 + 0.72 NI \text{ (mg/Kg } W^{0.75})$ at $NI = \text{Zero}$ then $EUN = UN = 187.27 \text{ (mg/Kg } W^{0.75})$. While, for goats under 35°C, the correlation coefficient between UN and IN was 0.62, intercept was 71.87 and regression coefficient was 0.44 and regression formula was $UN \text{ (mg/Kg } W^{0.75}) = 71.87 + 0.44 NI \text{ (mg/Kg } W^{0.75})$ at $NI = \text{Zero}$ then $EUN = UN = 71.87 \text{ (mg/Kg } W^{0.75})$.

Metabolic fecal nitrogen (MFN)

For goats under 25°C, the correlation coefficient was 0.22, intercept was 243.36 and regression coefficient was 0.07, then regression formula was $FN \text{ (mg/Kg } W^{0.75}) = 243.36 + 0.07 NI \text{ (mg/Kg } W^{0.75})$. At nitrogen intake = zero then $FN = MFN = 243.36 \text{ (mg/Kg } W^{0.75})$. While, for goats under 35°C, the correlation coefficient was 0.27, intercept was 213.31 and regression coefficient was 0.08 then regression formula was $FN \text{ (mg/Kg } W^{0.75}) = 213.31 + 0.08 NI \text{ (mg/Kg } W^{0.75})$. At nitrogen intake = zero the $FN = MFN = 213.31 \text{ (mg/Kg } W^{0.75})$.

Biological value of protein (BV)

The biological value of protein quantified using the formula suggested by Mitchell (1924). The biological value of dietary protein by goats under 25°C averaged 51.60 % vs. 48.29 % for goats under 35°C .

True digestibility of protein

True digestibility of protein was calculated using the formula suggested by Mitchell (1924). True digestibility of protein for goats under 25°C averaged 86.74 % vs. 86.91 for goats under 35°C .

Nitrogen requirement for maintenance of goats under 25°C was calculated to be 5.5 g CP/ KgW^{0.75} or 3.6 g DCP/ KgW^{0.75} based on 66.33 % protein digestibility and average body weight = 29.5 Kg. For goats under 35°C nitrogen requirement for maintenance was found to be 4.15 g CP / KgW^{0.75} or 2.87 g DCP / KgW^{0.75} based on 69.35 % protein digestibility and average body weight = 30.31 Kg.

Graphical method

Data of nitrogen balance (mg/KgW) for goats fed rations containing varying levels of dietary protein under 25°C and 35°C was plotted in Figure 1. The cross points (a) and (b) represented the minimum and maximum nitrogen intake, at nitrogen equilibrium (NB = 0). The respective values (mg/KgW) of (a) and (b) were 357 and 415 for animal (No. 1), 420 and 445 for animal (No. 2), 335 and 435 for animal (No. 3), 357 and 500 for animal (No. 4), 125 and 278 for animal (No. 5), 370 and 386 for animal (No. 6), 188 and 260 for animal (No. 7) and 345 and 395 for animal (No.8) for goats under 25°C and 35°C respectively.

For goats under 25°C the overall mean of maintenance requirement was found to be 5.95 g CP/ KgW^{0.75} or 3.94 g DCP/ KgW^{0.75} based on 66.33% protein digestibility and average body weight = 29.5 Kg.

For goats under 35°C the overall mean of maintenance requirement was 4.30 g CP/KgW^{0.75} or 2.98 g DCP/KgW^{0.75} based on 69.35 % protein digestibility and average body weight = 30.31 Kg.

The nitrogen balance trials based on feeding rations containing varying levels of protein content indicated the following assessment of nitrogen requirement for Egyptian Nubian goats as determined by the three methods.

For goats under 25°C the requirement was found to be 5.63 g CP/ KgW^{0.75} or 3.71 g DCP/ KgW^{0.75} based on 66.33% protein digestibility and average body weight = 29.5 Kg. For goats under 35°C the requirement was 4.31 g CP/ KgW^{0.75} or 2.98 g DCP/ KgW^{0.75} based on 69.35 % protein digestibility and average body weight = 30.31 Kg.

Digestible crude protein for maintenance was 2.9 g/ KgW^{0.75} for Egyptian Baladi goats Helal (2002) and NRC (1981) recommended 4.15 g CP/ KgW^{0.75} or 2.82 g DCP/ KgW^{0.75} for goats.

The present study showed that the protein requirement for maintenance of Egyptian Nubian goats was higher under 25°C ambient temperature than under 35°C. This result confirms to the statement of Ames and Willms (1977) that protein requirement for lambs is likely to be reduced during heat stress.

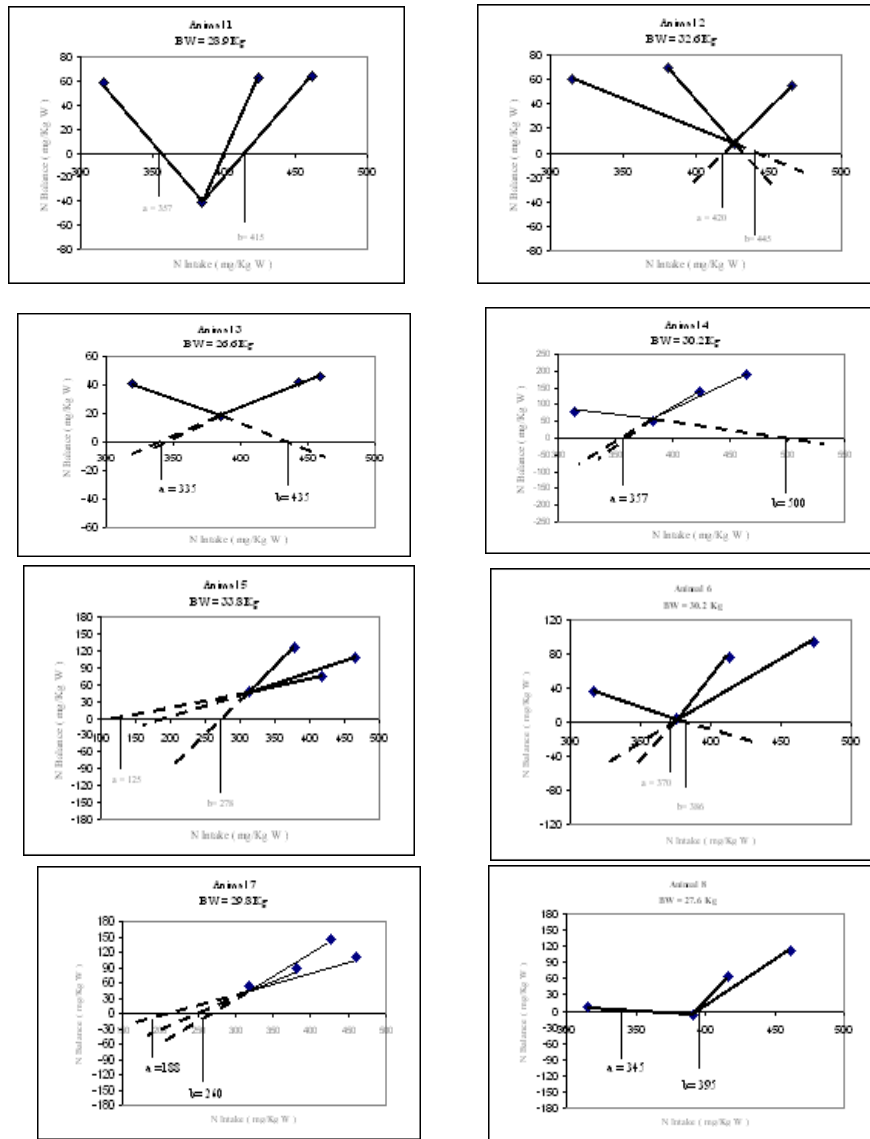


Fig 1. Maintenance nitrogen requirements with graphical method for goats under 25°C and 35°C

It is clear that heat stress reduced protein requirement for maintenance by about 25%. This reduction in requirement reflect the reduction in nitrogen out go under heat stress. Animals reduced the amount of feces voided by 11.5% as well as the concentration of nitrogen in urine by 56.1 and feces by 20% the reduction could by a part integrated in general reduction in the metabolic heat production in counteraction to the high environmental temperature? Is it triggered by the endocrine - renal mechanism in response to the protein metabolic wastes alongside water balance?

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تأثير الإجهاد الحراري على الإحتياجات الحافظة من البروتين للماعز النوبي المصري

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أجريت هذه الدراسة بمحطة البحوث الزراعية (معمل فسيولوجي الحيوان)، كلية الزراعة جامعة القاهرة بالجيزة بالتعاون مع معهد بحوث الإنتاج الحيواني التابع لمركز البحوث الزراعية بالجيزة. استهدفت هذه الدراسة معرفة تأثير الإجهاد الحراري على الإحتياجات الغذائية الحافظة من البروتين في الماعز النوبي المصري (الزرايبي). حيث قدرت الإحتياجات الحافظة من البروتين تحت درجتى حرارة ٢٥°م و ٣٥°م من خلال تجربة موازين النيتروجين. حيث تم تغذية ٨ ذكور ماعز نوبي مصري متوسط وزنها ٣٠.٧٥ كجم على ٤ علائق متساوية فى الطاقة و متدرجة فى نسبة البروتين ٩.٨٣، ١٣.٢٢، ١١.٨١، ١٤.٧٤ و تم حساب الإحتياجات بإستخدام ٣ طرق للحساب. الطريقة الإحصائية، طريقة العوامل و كذلك الطريقة البيانية. أدى الإجهاد الحراري إلى خفض الإحتياجات الحافظة من البروتين بمقدار ٢٥% تقريبا حيث كان متوسط الإحتياجات الحافظة من البروتين الخام ٥.٦٣ جم/٠.٧° تحت درجة حرارة ٢٥°م و ٤.٣١ جم/٠.٧° تحت ٣٥°م .