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ENERGY AND PROTEIN REQUIREMENTS OF GROWING PELIBUEY SHEEP UNDER TROPICAL CONDITIONS ESTIMATED FROM A LITERATURE DATABASE ANALYSES

[NECESIDADES DE PROTEÍNA Y ENERGÍA DE OVINOS PELIBUEY EN CRECIMIENTO EN CONDICIONES TROPICALES ESTIMADOS A PARTIR DEL ANÁLISIS DE UNA BASE DE DATOS DE LA LITERATURA]

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SUMMARY

Data from previous studies were used to estimate the metabolizable energy and protein requirements for maintenance and growth and basal metabolism energy requirement of male Pelibuey sheep under tropical conditions were estimated. In addition, empty body weight and mature weight of males and female Pelibuey sheep were also estimated. Basal metabolism energy requirements were estimated with the Cornell Net Carbohydrate and Protein System – Sheep (CNCPS-S) model using the *a1* factor of the maintenance equation. Mature weight was estimated to be 69 kg for males and 45 kg for females. Empty body weight was estimated to be 81% of live weight. Metabolizable energy and protein requirements for growth were 0.106 Mcal ME_m/kg $LW^{0.75}$ and 2.4 g MP/kg $LW^{0.75}$ for males. The collected information did not allowed appropriate estimation of female requirements. The basal metabolism energy requirement was estimated to be 0.039 Mcal ME_m/kg $LW^{0.75}$. Energy requirements for basal metabolism were lower in Pelibuey sheep than those reported for wool breeds even though their total requirements were similar.

Key words: Energy and protein; Pelibuey sheep; CNCPS-S.

RESUMEN

Se estimaron las necesidades de energía y proteína metabolizable para mantenimiento y crecimiento y las necesidades energéticas para el metabolismo basal de machos Pelibuey bajo condiciones de trópico. Adicionalmente se estimó el peso vivo vacío y el peso a la madurez en machos y hembras. Las estimaciones se realizaron empleando una base de datos de experimentos previos. Se estimó las necesidades para el metabolismo basal empleando el factor *a1* del modelo del sistema de Carbohidratos y Proteína Neta de Cornell–Ovinos (CNCPS-S) a partir de la ecuación de mantenimiento. Se estimó el peso maduro de machos y hembras Pelibuey en 69 kg y 45 kg respectivamente. Las necesidades de energía y proteína metabolizable para crecimiento de machos se estimaron en 0.106 Mcal EM_m/kg $PV^{0.75}$ y 2.4 g PM/kg $PV^{0.75}$ respectivamente. La información colectada no permitió una estimación confiable de las necesidades de las hembras. Las necesidades energéticas para el metabolismo basal fueron estimadas en 0.039 Mcal EM_m/kg $PV^{0.75}$. Las necesidades de energía para el metabolismo basal estimadas en el presente estudio fueron menores en comparación con reportes previos en razas lanares pero las necesidades totales fueron similares.

Palabras clave: Requerimientos de energía y proteína; Ovinos Pelibuey; CNCPS.

INTRODUCTION

Sheep production in Mexico has grown significantly, particularly in the Yucatan Peninsula in which the sheep population has more than doubled from 43,003 in 1990 to 87,508 in 2004 (SIAP, 2007). The Pelibuey and Black Belly breeds predominate in the Yucatan Peninsula as they do throughout the Mexican tropics, even though other breeds (e.g. Katahdín and Dorper) have been recently introduced through crossbreeding programs.

The main purpose of most sheep production systems in Yucatan is meat production (Torres et al., 2004) and these systems tend to involve a confined intensive growth stage after weaning. Under these conditions, energy is the first limiting nutrient for growth and rations are consequently formulated to meet energy requirements. These rations, however, are extrapolated from research on wool sheep in temperate climates. Very little research has been done on the nutritional needs of hair sheep in the tropics. Some authors have stated that Pelibuey breed has greater energy requirements than wool breeds, although this conclusion was based on limited data (Solís et al., 1991; Bores et al., 2001). The Pelibuey's productive potential has been considerably improved through selection and crossbreeding; therefore, its nutritional requirements should be revised and updated.

Nutritional models, such as the Cornell Net Carbohydrate and Protein System for sheep (CNCPS-Sheep; Cannas et al., 2004) and the Small Ruminant Nutrition System (SRNS, Cannas et al., 2007a; 2007b, 2007c) are continuously developed but updated data are not available for some of the parameters required by these models to predict the performance of Pelibuey sheep, including mature weight, empty body weight and maturity index. Given this, as well as the suggestion that the Pelibuey breed might have higher energy requirements for growth (Solís et al., 1991; Bores et al., 2001), the aim of the study was to estimate the protein and energy requirements for growth of Pelibuey sheep and to generate data on parameters than can be incorporated into nutrition models.

MATERIALS AND METHODS

Estimation of empty body weight

Adjusted empty body weight (EBW) was determined from data of a previous research studies on Pelibuey sheep that included carcass yield, organ weight and gastrointestinal fill (see Table 3 for references).

Estimation of maintenance and weight gain requirements

Data from 29 experiments with a total of 1304 sheep (1112 males and 192 females) and 93 diets during the growth-finishing stage were used in this study. Pelibuey sheep were used in 26 of these experiments and crossbreds between Pelibuey and paternal wool breeds (Dorset, Hampshire or Suffolk) in the remaining 3 experiments (Duarte, 2007) (Table 1). Animals were fed in growth corrals with complete diets formulated with agricultural by-products (e.g. corn stover), agroindustrial by-products (e.g. cane molasses), poultry manure, soybean or sunflower meal, grains (mainly corn and sorghum), grass hay, salt, minerals and additives, among other ingredients. Only 3% of the diets included a concentrate as a feed supplement using live weight (LW) as criteria for supplementation level and were fed in *ad libitum* regimen. The main characteristics of the diets are shown in Table 2. Values were obtained from the experimental data reported in the literature and used as input in the original CNCPS-S model (Cannas et al., 2004) to yield data on Rumen nitrogen balance (RNB) and total digestible nutrients (TDN) (Duarte, 2007).

Estimates of energy and protein requirements for maintenance and daily weight gain (DWG) were calculated using multiple linear regression analyses including metabolizable energy intake (MEI Mcal/kg $LW^{0.75}$) obtained from the literature reported values collected in database), daily metabolizable protein intake (MPI g/kg $LW^{0.75}$) calculated from the CNCPS-S, and weight gain in males and females. Regression analyses were performed using Minitab 15 statistical software procedures (Minitab, 2007). Equations are shown below.

$$NI = a\ LW^{0.75} + b\ DWG \qquad \text{(eq. 1)}$$

$$NI = a\ LW^{0.75} + b\ DWG + c\ LW^{0.75} \qquad \text{(eq. 2)}$$

Where:

NI = nutrient intake, i.e. metabolizable energy (Mcal/d) or metabolizable protein (g/d)
a = metabolizable energy or protein requirements for maintenance (Mcal/kg $LW^{0.75}$ or g/kg $LW^{0.75}$)
b = metabolizable energy or protein requirements for growth (Mcal/g DWG or g/g DWG)
c = metabolizable energy (Mcal/kg $LW^{0.75}$) or protein (g/kg $LW^{0.75}$) requirements for growth (when maintenance energy requirement was estimated parameter 'c' stands for protein and vice-versa).

Estimation of energy requirement for basal metabolism

Basal metabolism (*a1*) was estimated using the CNCPS-S model with the adjustments proposed by Cannas et al. (2004) and based on the experimental diets in the database. Preliminary assessment showed that nutrient requirement estimations for females were not reliable due to the number of data and were not further assessed. Given that the DWG and nutrient intake variables were known, the performance prediction equation (eq. 3) was rearranged to estimate basal metabolism (*a1*).

Table 1. General characteristics of sheep in database (males n=1112, females n=192) [1].

	Initial weight (kg)	Final weight (kg)	Average weight (kg)	Empty Weight (kg)	Metabolic Weight ($kg^{0,75}$)	Age (years)
Males						
Mean	21.6	34.9	28.2	22.9	12.2	0.5
Maximum	34.0	47.6	37.9	30.8	15.3	2.0
Minimum	12.0	26.8	19.3	15.7	9.2	0.3
SD	5.4	4.6	4.4	3.6	1.4	0.3
Females						
Mean	27.7	34.0	30.6	25.2	13.0	2.5
Maximum	32	42.1	36.7	30.3	14.96	3.0
Minimum	10.4	23.3	16.9	13.9	8.3	0.3
SD	6.4	4.8	5.1	4.2	1.7	1.1

[1]1 From Duarte Vera (2007)

Table 2. Main characteristics of diets (males n=77, females n=16)[1]

	DMI	MEI	eNDF	CP	RNB*	Forage	TDN*
Males							
Mean	1.3	3.2	13.83	13.5	8.10	34.1	51.1
Maximum	2.0	5.6	32.91	20.0	16.85	73.4	79.5
Minimum	0.6	1.6	0.13	5.1	-3.67	6.0	29.9
SD	0.3	0.83	6.90	2.8	5.70	17.4	10.6
Females							
Mean	1.2	2.9	17.38	12.0	4.63	45.8	52.0
Maximum	1.7	4.8	22.95	16.9	14.46	68.7	62.3
Minimum	0.6	1.3	9.86	8.9	-0.05	13.2	32.6
SD	0.33	1.1	4.30	2.7	4.41	18.2	9.0

1 From Duarte Vera (2007)
DMI = dry matter intake (kg/animal/day);
MEI = metabolizable energy intake (Mcal ME/animal/day)
eNDF = effective neutral detergent fiber as a percentage of ration NDF
CP = crude protein, as a percentage of dry matter
RNB = rumen nitrogen balance
Forage = forage content as a percentage of diet dry matter
TDN = total digestible nutrients, as a percentage of dry matter
SD = standard deviation of the mean
*Values calculated with the CNCPS-S model (Cannas et al., 2004)

Table 3. Estimation of empty body weight (EBW) in Pelibuey sheep.

Sex	Age (months)	Initial weight (kg)	N	System	Weight at death (kg)	EBW * (%)	Reference
Males	3	16	15	Grazing	22.5	85.3	García et al., (1998)
Males	6	15.6	48	Supplementation	20-30	70.7	Romano et al., (1983)
Males	14	20.9	36	Feedlot	36	81.9	Martínez et al., (1990)
--	--	--	77	--	--	81.0	Cantón et al., (1992)
Males	5.5	28	4	Feedlot	42.3	83.3	Carvalho et al., (2005)
Males	5.5	30.4	4	Supplementation	43.3	81.5	Carvalho et al., (2005)
Males	5.5	29.5	4	Creep feeding	38.4	84.3	Carvalho et al., (2005)
Females	65	31.7	61	Supplementation	31.6	82.2	Martínez et al., (1987)
Females	--	--	16	Feedlot		82.7	Cantón et al., (1992)
Average		25.3			35.1	81.4	
SD		± 6			± 6.8	± 4	

*EBW as percentage of Body weight

$$EM_m = \{[SBW^{0.75} * a1 * a2 + e^{(-0.03*AGE)}] + (-0.09 * MEI * k_m) + ACT + NE_{mes} + UREA\}/k_m \quad \text{(eq.3)}$$

Where:
$SBW^{0.75}$ = shrunk body weight in Kg $LW^{0.75}$
a1 = energy requirement for thermoregulation in fasting metabolism (Mcal ME/ Kg $LW^{0.75}$).
a2 = adjustment factor for effect of environmental temperature (1 + 0.0091 x C); C = 20 – average temperature in previous month (ºC).
$e^{(-0.03*AGE)}$ = Adjustment for age in years.
MEI = ME intake in Mcal/day (0.106 Mcal ME/$kg^{0.75}$ obtained from equation 1)
k_m = energy utilization efficiency coefficient, fixed at 0.644.
ME_m = metabolizable energy requirement for basal metabolism in Mcal/day
ACT = effect of activity on maintenance requirements in Mcal/day, according to the equation of Cannas et al. (2004), considering animals walked 50 m on flat surfaces only.
NEmes = additional energy to compensate cold stress (this figure was considered to be 0 due to the predominant tropical climate)
UREA = energy cost in Mcal ME_m for elimination of excess N as urea.

The energy adjustment for cold stress equilibrium was not included in this equation due to climate differences between the region where the equation was developed and the Mexican tropics. MEI and $SBW^{0.75}$ were taken from the original data base; environmental data (i.e. average temperature in previous month in ºC) were acquired from the National Water Commission (Comisión Nacional del Agua -CNA) data base for the Yucatan Peninsula from four points (Merida Meteorological Observatory, Tizimín, Valladolid and Mocochá meteorological stations) nearest where most of the experiments in the data sample were done. For those cases in which the season and year of the beginning of the experiment were not stated, or in those done outside the Yucatan Peninsula but in tropical conditions, the average monthly temperature at the Merida Meteorological Observatory for the last 45 years (26.1 °C) was used in the CNCPS-S.

Estimation of mature weight

Age and weight data from birth to approximately 10 years of age were collected for Pelibuey sheep (n = 3,320 male; 1,857 female) from ranches and institutions in the region and arranged in separates datasets. These data were used to estimate growth curves for males and females (Brody, 1945) and then to estimate maturity rate (k) and mature weight (A) (Jenkins and Leymaster, 1993) (Equation 4):

$$Y_t = A(1 - Be^{-kt}) \quad \text{(eq. 4)}$$

Where:
Y_t = LW at time *t*
A = mature weight
B = relative weight change from birth to mature weight
k = maturity rate
t = age in days
The data were estimated and compared with a t test using the GraphPad Prism 4 (Graph Pad Prism 2003) program. The non-linear regression parameters were estimated by minimizing the sum of the squares of each value's relative distances from the predicted curve (Motulsky and Christopoulos, 2003) (equation 5), that is:

$$\sum[Y_{observed} - Y_{predicted}/Y_{observed}]^2 \quad \text{(eq. 5)}$$

RESULTS AND DISCUSSION

Database profile

A total of 83% of the experiments were done using growth-stage males, 7% with growth-stage females and 10% using initial gestation stage females. LW and initial age were highly variable between experiments, with an average of 21.6 kg and 0.5 years in males and 27.7 kg and 2.5 years in females (Table 1). Data for crude protein content, effective neutral detergent fiber, total digestible nutrients, dry matter intake (DMI), metabolizable energy, forage content and animal rumen nitrogen balance are shown in Table 2. Most of the animals had a positive rumen N balance, with only 6% of males and 25% of females with a negative balance as calculated with the CNCPS-S model.

Empty body weight

Estimation of basal metabolism nutritional needs is influenced by the amount of body tissue versus LW, which in turn depends on the gastrointestinal fill. Data on gastrointestinal fill is limited for Pelibuey sheep, the collected dataset showed that on average it was 81.4% ± 4 of the LW percentage a value 18% greater than in wool sheep (Table 3). Empty body weight (EBW) is affected by feed intake level and in turn by other factors such as diet type (NRC, 1985). However, the experimental data included in the database did not include enough information to generate a model that included these effects. An empirical relationship was generated between EBW and DMI percentage versus live weight (LW), assuming linearity and using relative values of 80 % minimum and 96% maximum for EBW and 3 to 7 % DMI versus LW:

$$EBW = LW * 0.96 \quad \text{if } DMI =< 3\% \, LW \quad \text{(eq. 6)}$$

$$EBW = LW * (1.08 - 0.04*DMI) \text{ if } DMI =>3\% \ LW \quad \text{(eq. 7)}$$

The AFRC (1993) provides a requirement of 0.0687 Mcal ME/kg $LW^{0.75}$ for basal metabolism. In contrast, the NRC (1985) suggested that maintenance energy starts from 0.063 Mcal NE/kg $LW^{0.75}$ and an adjustment to EBW is necessary, assuming 6.1 kg gastrointestinal fill for a 40 kg animal (equivalent to 15.2 % of gastrointestinal fill). This adjustment would produce a value of 0.056 Mcal NE_m/kg $LW^{0.75}$ which is equivalent to a difference of 11.1 % in the requirement. However, the difference in gastrointestinal fill in Pelibuey sheep is 18%. These effects are quite remarkable and accurate data from Pelibuey animals are needed to determine EBW, and therefore better estimate SBW, and/or directly calculate SBW.

Energy and protein requirements

The linear regressions for MPI and MEI on DWG (Table 4) indicated that protein and energy requirements had linear pattern for both sexes. For males, most of the data is within 100 to 300 g/d of DWG. However, the data had not enough points for females.Therefore, the results for females were no longer included and are not reported. The r^2 improved considerably and the equation variation coefficient decreased when ME and MP were estimated with multiple regressions (Table 3). Using DWG and ME as predictors of the MP requirements yields a negative value indicating a catabolic and salvage/recycling process for protein when DWG and energy intake is equal to zero. Similarly, the protein requirements in the multiple regression for ME estimation results in positive values indicating the endogenous MP loss when animal are fed maintenance energy levels.

Estimated energy required for maintenance, by males, expressed as Mcal/ kg $LW^{0.75}$, energy requirements was 0.143 Mcal ME/kg $LW^{0.75}$ (Table 4). One of the main factors involved in calculating maintenance energy requirements is basal metabolism and Cannas et al. (2006) proposed an adjustment to this factor, decreasing it from 0.062 to 0.052 Mcal ME/kg $LW^{0.75}$, to improve predicted LW gain in hair sheep using the CNCPS-S. However, the average value generated using the present data when calculating the *a1* factor for each diet used in the experiments with males (n = 77) was 0.039 Mcal ME_m/kg $LW^{0.75}$, lower than the 0.062 considered in the original CNCPS-S model (Cannas et al., 2004) and the 0.052 suggested by Cannas et al. (2006). Using the 0.039 value improved predicted LW gain in Pelibuey sheep with the CNCPS-S (Duarte, 2007), supporting the hypothesis that basal metabolism energy requirements in this breed are lower than in wool breeds. Maintenance energy requirements would consequently be less than previously reported (Solis et al., 1991; Bores et al., 2001). A possible explanation for this may be higher gastrointestinal fill in the Pelibuey breed compared to wool breeds, which, together with its higher bone proportion of LW (30.5 % in Pelibuey vs. 16 to 24 % in wool breeds; Martínez et al., 1987), provide this breed with a smaller amount of metabolically active tissue.

Mature weight

Average mature weight based on the collected data was 69.8 ± 1.98 kg for males and 44.6 ± 1.276 kg for females (Figure 1). Growth equations for males (eq. 8) and females (eq. 9) respectively were:

$$LW_t(kg) = 69.8 (\pm 1.98) * (1 - 0.963 (\pm 0.0011) * e^{-0.0033 (\pm 0.00012) * t}) \quad r^2 = 0.904 \quad \text{(eq. 8)}$$

$$LW_t(kg) = 44.6(\pm 1.27) * (1 - 0.943 (\pm 0.0017) * e^{-0.0031 (\pm 0.0001) * t}) \quad r^2 = 0.923 \quad \text{(eq. 9)}$$

It is noteworthy that in some animals aprox. 4-5 years of age weights up to 100 kg for males and 70 kg for females were observed.

Table 4. Multiple regressions between daily weight gain (DWG), metabolizable protein intake and metabolizable energy intake over DWG in male Pelibuey sheep.

Equation	R^2	P	CV
MP = 2.40 (± 0.6185) + 0.0285(±0.003328)* DWG	0.49	<0.01	28.5
ME = 0.143 (±0.01324) + 0.000686 (±0.00007124)*DWG	0.55	<0.01	15.9
MP = -2.41 (±0.6891) + 0.00538 (±0.003471) *DWG + 33.7 (±3.761)* ME	0.76	<0.01	1.4
ME = 0.106 (±0.01012) + 0.000246 (±0.00006986)* DWG + 0.1154 (±0.001723) *MP	0.78	<0.01	11.5

MP = metabolizable protein (g/kg $LW^{0.75}$)
ME = metabolizable energy (Mcal/kg $LW^{0.75}$)
DWG = daily weight gain (g/d)
±SE = standard error
r^2 = determination coefficient
P = statistical probability
CV = coefficient of variation

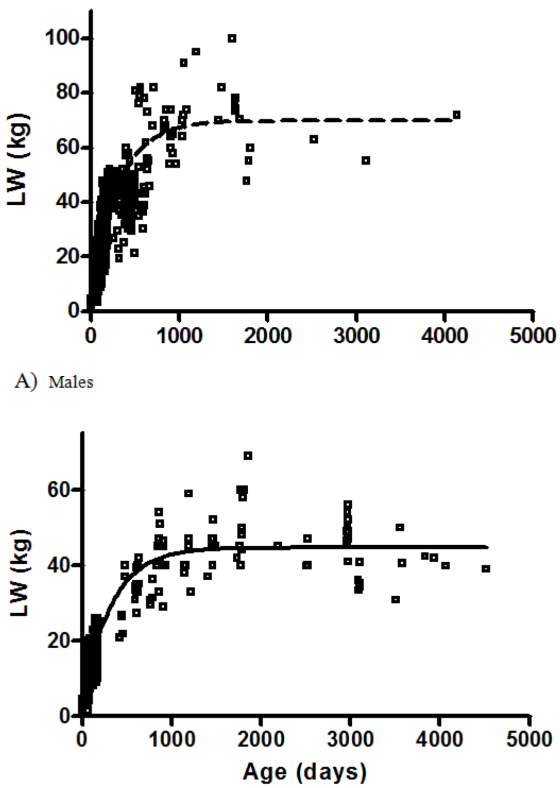

Figure 1. Growth curve for Pelibuey sheep a) males (n=3320), b) females (n=1857)

To calculate net energy requirements for weight gain (NE_g), the NRC (1985) uses the equation: $NE_g = 276$ LWG x $W^{0.75}$, where LWG is expected LW gain and $W^{0.75}$ is mature weight (assumed to be 115 kg), with a positive adjustment of 21 Kcal per 10 kg mature weight below the assumed weight. However, the mature weight of Pelibuey sheep has increased over 40% versus the breed standard (Berruecos, 1975). Determination of a more accurate mature weight for Pelibuey sheep allowed better estimation of the corresponding maintenance and weight gain energy needs, and could be incorporated into any other predictive model that uses this variable.

When using proper mature weight and SBW values, the energy requirements of growing Pelibuey sheep were similar to those of wool breed sheep. Genetic improvement programs may have increased this breed's productive potential to the point where it exhibits weight gains similar to wool breeds. This would allow establishment of more objective criteria which will in turn produce similar energy requirements.

CONCLUSIONS

This study indicated that basal metabolism energy requirements are lower in Pelibuey sheep than in wool breeds. However, the total energy requirements for weight gain in Pelibuey sheep are greater than in wool breeds, although the difference is less than previously reported. The mature weight in Pelibuey sheep is about 69 kg for males and 45 kg for females. The present database was insufficient to generate trustworthy energy and protein requirements results for female Pelibuey.

REFERENCES

AFRC, 1993. Necesidades energéticas y proteicas de los rumiantes. CAB Internacional Editorial Acribia, Zaragoza (España). Cap. 2 Necesidades de Energía Metabolizable, pp. 25-37.

Berruecos, J.M.V., Valencia, Z.M., Castillo, R.H., 1975. Genética del Borrego Tabasco o Peligüey. Técnica Pecuaria México 29: 59-56.

Bores, R.Q., Velásquez, M.A., Heredia, M.A., 2001. Evaluación de niveles energéticos y pesos de sacrificios de corderos terminales Suffolk X Pb. Procceedings Segundo Congreso Latinoamericano de especialistas de pequeños rumiantes y camélidos sudamericanos Mérida Yucatán México.

Brody S., 1945. Bioenergetics and Growth. Reinhold Publishing, NY.

Cannas, A., Tedeschi, L.O., Fox D.G., Pell, A.N., Van Soest, P.J., 2004. A mechanistic model for predicting the nutrient requirements and feed biological values for sheep. Journal Animal Science 82: 149-169.

Cannas, A; Tedeschi, LO; Atzori, AS; Fox, DG., 2006. Prediction of Energy Requirement for Growing Sheep with the Cornell Net Carbohydrate and Protein System. In: Kebreab, E., Dijkstra, J., Bannink, A., Gerrits, W.J.J. and France, J. (eds), Nutrient Digestion and Utilization in Farm Animals. Modelling Approaches. CABI Publishing, Wallingford, UK. Pp. 99-113.

Cannas, A., Tedeschi, L.O., Atzori, A.S., Fox, D.G., 2007a. Prediction of the growth rate of kids with the Small Ruminant Nutrition System. In: Annual Meeting of the Brazilian Society of Animal Science, 44, July 27, 2007, Jaboticabal, SP, Brazil. Pp- 1-3-

Cannas, A., Tedeschi, L.O., Fox, D.G., 2007b. Prediction of metabolizable energy intake and energy balance of goats with the Small Ruminant nutrition System. In: 2nd

International Symposium of Energy and Protein Metabolism and Nutrition, September 9-13, 2007, Vichy, France. Pp. 569-570.

Cannas, A., Tedeschi, L.O., Fox, D.G., 2007c. The Small Ruminant Nutrition System: development of a goat submodel. Proceedings American Society of Animal Science, San Antonio, TX. Pp. 505.

Carvalho, S., Da Silva, M. de F., Cerutti, R., Kieling, R., De Oliveira, A., Deleastre, M., 2005. Performance and live weight components of lambs submitted to different feeding systems. Ciencia Rural. 35:650-655.

Duarte Vera, F., 2007. Evaluación del CNCPS-S para estimar los requerimientos de energía durante el crecimiento de borregos Pelibuey. Tesis de doctorado Universidad Autónoma de Yucatán, México. 98 pp

Graph Pad Prism 4., 1994-2003. Graph Pad Software, San Diego California, USA.

García, M.J.A., Núñez, G.F.A., Rodríguez, A.F.A., Prieto, C., Molina, D.N.I., 1998. Calidad de la canal y de la carne de borregos Pelibuey castrados. Técnica Pecuaria México 36: 225-232.

Canton, J.G.C., Velazquez, A.M., Castellanos, A.R., 1992. Body Composition of pure and crossed blackbelly sheep. Small Ruminant Reseach, 7:61-66.

Jenkins, T.G. and Leymaster, K.A., 1993. Estimates of Maturing Rates and Masses at Maturity for Body Components of Sheep. Journal Animal Science 71: 2952-2957.

Martínez Avalos., A.M.M., Bores Quintero, R.F., Castellanos Ruelas, A.F., 1987. Zoometría y predicción corporal de la borrega Pelibuey. Técnica Pecuaria México 25: 72-84.

Martinez Avalos, A.M.M., Bores Quintero, R., Velazquez Madrazo, P.A., Castellanos Ruelas, A.F., 1990. Influencia de la castración y del nivel energético de la dieta sobre el crecimiento y composición corporal del borrego pelibuey. Tecnica Pecuaria Mexico, 28:125-132.

Minitab, 2007. Minitab Release 15. Minitab Reference Manual. Minitab, State College, Philadelphia, USA.

Motulsky, H., Christopoulos, A., 2003. Fitting models to biological data using linear and nonlinear regression. A practical guide to curve fitting. Graph Pad Software, San Diego California, USA.

NRC 1985. Nutrient Requirements of Sheep. 5th Revised Edition, National Academy Press Washington, D.C.

SIAP, 2007. Secretaría de Agricultura Ganadería Desarrollo Rural Pesca y Alimentación. Coordinación General de Ganadería. Servicio de Información Estadística Agroalimentaria y Pesquera, México, febrero de 2007. http//:www.siap.sagarpa.gob.mx/ar_comcadagral.html.

Romano, M.J.L., Hernandez, G.J., Castellanos, R.A., 1983. Repercusion del valor nutritivo de la dieta sobre el crecimiento del borrego pelibuey. Tecnica Pecuaria Mexico. 45:67-79.

Solís, R.G.E., Castellanos, A.F., Velázquez, M., Rodríguez, G.F., 1991. Determination of nutritional requirements of growing hair sheep. Small Ruminant Research 4: 115-125.

Torres, A.J.F., Cámara, S.R., Aguilar, C.A.J., López, C.C., Ruíz, P.C.H., Vargas, M.J.J., Calderón, Q.J.A., Cánto D.J.H., Canul, K.H.L., 2004. Transferencia de Tecnología a Productores de Ovinos del Estado de Yucatán. Informe Final. FMVZ-UADY. Fundación Produce Yucatán A. C. Mérida Yucatán México. 123 pp.

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